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Editor
ROY WALDO MINER

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*SECTION OF PHYSICS AND CHEMISTRY**

CHEMILUMINESCENCE AS A TOOL IN VOLUMETRIC ANALYSIS**

By FREDERIC KENNY***

The chief aim in this work was the selection of chemiluminescent materials which would give good end points in highly colored or turbid solutions when used with (1) oxidimetric, (2) precipitation, and (3) neutralization reactions.

Oxidimetric Titration

The oxidimetric reaction selected for study was the oxidation of ferrous ion by ceric ion. Since the calculated and experimental values for the stoichiometric potential have been shown to be approximately 1.1 volts, the indicator selected, in order to give good results, must begin to emit light when the potential rises to some value on the steep portion of the titration curve, and as close as possible to 1.1 volts. Furthermore the indicator must function in an acid solution.

The material selected was first prepared by Wöhler in 1863.[1] Although Wöhler called it *silicone*, to avoid confusion with polymeric $R_2Si = 0$ compounds,[2] the present author has renamed it *siloxene indicator*. Kautsky[3, 4, 5, 6] has shown that when calcium silicide is treated with hydrochloric acid diluted with alcohol, in the dark at low temperature, $(Si_6H_6O_3)_n$ is formed,[3, 4] which appears to have the structure shown in FIGURE 1, in which six-membered silicon rings are joined edgewise through oxygen atoms.[4, 7] Each silicon atom holds an atom of hydrogen. This material is formed in infinitesimally thin sheets piled one upon another,[6, 8] with spaces between permitting penetration of liquid.[4, 6, 9] When concentrated hydrochloric acid is used in preparing the material in daylight at elevated temperatures, some hydrogen atoms are replaced by Cl or OH and some atoms of oxygen enter the silicon rings, as shown in FIGURE 2.[4] When this material is exposed to a solution in which the potential is rising, owing to titration with an oxidizing agent, a sufficiently high potential may be reached to cause the indicator to give out light.

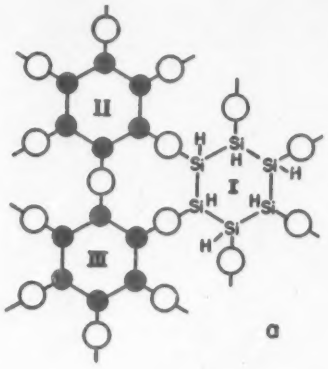

FIGURE 1. Structure of siloxene, showing six-membered silicon rings joined through atoms of oxygen. (Reproduced by permission of *Analytical Chemistry*.)

To test the behavior of the indicator,[10] ceric sulfate solution was standardized against ferrous solution potentiometrically, 26.48 ml. of ceric solution being required for titration of 25.00 ml. of ferrous solution. The stoichiometric potential was found to be approximately 1.09 volts.

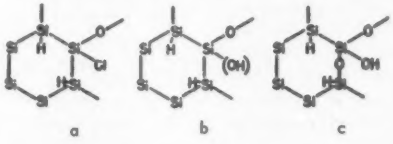

FIGURE 2. (a) Chlorosiloxene, (b) Hydroxysiloxene, (c) Oxidized siloxene. (Reproduced by permission of *Analytical Chemistry*.)

*The Section of Geology and Mineralogy held a meeting on May 3, 1954 at which a paper entitled "Some Aspects of a Trip Around the World with Notes on Geology" was read by Edward Sampson. No abstract of this paper has been received.

**This paper, illustrated with lantern slides, was the first of two papers presented at a meeting of the Section on May 4, 1954.

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TABLE 1

VOLUME OF CERIC SOLUTION EQUIVALENT TO 25.00 ML. OF FERROUS SOLUTION

Cobaltous ion absent		Cobaltous ion 0.1 /M present	
Ceric solution	*Deviation from mean*	*Ceric solution*	*Deviation from mean*
ml.	ml.	ml.	ml.
26.50	0.02	26.60	0.05
26.50	0.02	26.55	0.00
26.55	0.03	26.56	0.01
26.55	0.03	26.55	0.00
26.50	0.02	26.60	0.05
26.50	0.02	26.54	0.01
26.45	0.07	26.50	0.05
26.56	0.04	26.55	0.00
26.55	0.03	26.55	0.00
26.52	0.03 Mean	26.55	0.02 Mean

When, in the dark room, siloxene indicator was used in nine titrations of the ferrous solution, 26.52 ml. of the ceric solution was required. These results yielded an error of 1.5 parts/1000 and an average deviation of 1.1 parts/1000.

A similar series of titrations was carried out on ferrous solutions which were also 0.1 M with respect to cobaltous ion. The depth of color eliminated the possibility of using ordinary redox indicators. In this series, an end point of 26.55 ml. was obtained, with an error of 2.6 parts/1000 and a deviation of 0.75 parts/1000. The results of both series are shown in TABLE 1.

In the foregoing titrations the potential at the end point was found to be approximately 1.17 volts or 0.08 volts above the stoichiometric potential, and the pH was found to be approximately 0.23. The end point was not affected by variation in time of exposure of the indicator to the solution during titration. FIGURE 3 shows the end points for the two series superimposed on the mean standardization curve.

To eliminate the dark room the Dark Chamber Titrator shown in FIGURE 4 was employed in titrating ferrous solution and also ferrous solution which was deeply colored with 0.16 M chromic solution.[11] Five titrations of the first solution yielded an error of 1.3 parts/1000 and a deviation of 0.7 parts/1000 and five titrations of the colored solution yielded an error of 3.3

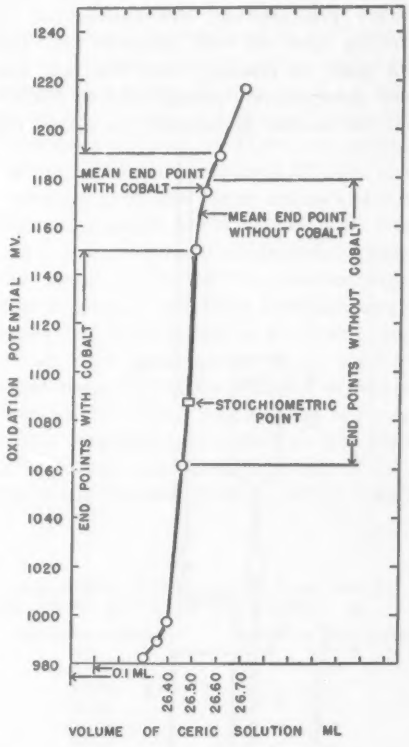

FIGURE 3. Average curve, showing end points without cobalt and with cobalt, using siloxene indicator. (Reproduced by permission of *Analytical Chemistry.*)

TABLE 2

VOLUME OF CERIC SOLUTION EQUIVALENT TO 30.00 ML. OF FERROUS SOLUTION

Chromic ion absent		Chromic ion 0.16 /M present	
Ceric solution	*Deviation from mean*	*Ceric solution*	*Deviation from mean*
ml.	ml.	ml.	ml.
29.95	0.04	29.88	0.11
29.90	0.01	29.90	0.07
29.90	0.01	30.01	0.04
29.92	0.01	30.00	0.03
29.90	0.01	30.05	0.02
29.91	0.02 Mean	29.97	0.05 Mean

parts/1000 and a deviation of 1.6 parts/-1000. These titrations are shown in TABLE 2.

Precipitation Titration

The second type of reaction studied, namely precipitation, was carried out by titrating lead ion with chromate ion. The end point is reached when the lead has been quantitatively precipitated as $PbCrO_4$ and the excess dichromate ion raises the potential to the point at which the siloxene emits light. Since the potential obtained is a function not only of the activity of the dichromate ion but of the hydronium ion as well, the optimum pH range was determined. The upper limit was established by adding indicator to distilled water and measuring the light obtained when one drop of potassium chromate solution was added. The light was detected by means of a Photovolt Multiplier Photometer 520-A, with which one unit on the scale used represented 0.002 microlumen.[12] From pH 8 to pH 3 insufficient light was emitted to give an end point, whereas below a pH of 3 adequate light was obtained.

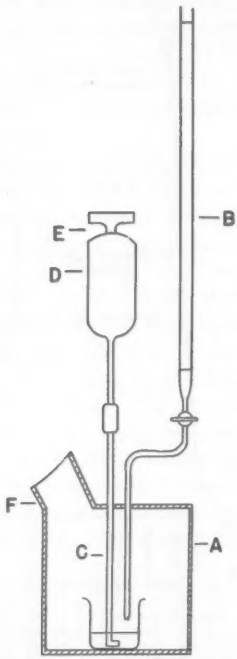

FIGURE 4. Dark Chamber Titrator. (Reproduced by permission of *Analytical Chemistry.*)

In order to check this upper limit and also to determine the lower limit, 30.00 ml. portions of 0.1000 M lead solution were titrated with 0.1000 M potassium chromate at a variety of pH values. When the pH values were less than 1.9 the end point was reached too soon, and when greater than 3 the end point was reached too late. The desirable pH range is thus 1.9 to 3, and this range was employed in all subsequent titrations.

To test the siloxene end point, sixteen 30.00 ml. portions of the lead solution when titrated with the chromate solution, yielded an end point of 29.98 ml., an error of 0.67 parts/1000 and a deviation of 1.3 parts/-1000. These results are shown in TABLE 3.[13]

To study the possibility of interference by other metals, solutions which were 0.1 M with respect to an additional metal ion as

well as being 0.1000 M with respect to lead were titrated. The additional metal ions were respectively: Mn^{++}, Ni^{++}, Fe^{+++}, Zn^{++}, Ca^{++}, and Mg^{++}. Most of the errors were between one and two parts/1000. The largest error, which was encountered with the zinc solution, was three parts/1000.

Neutralization Titration

The reaction selected to illustrate a neutralization titration was between NaOH and HCl. A chemiluminescent indicator, highly sensitive to slight changes in pH was employed, as shown in FIGURE 5. Here the hydrogen peroxide functions as an oxidizing agent,[14, 15, 16, 17] and the hemoglobin as a catalyst.[18, 19, 20] Hydroxyl ions remove protons from the luminol to form the anion before the oxidation, which emits light, can proceed.[21, 22, 23, 24, 25] Light is emitted when a pH of 6 is reached and increases to a maximum at a pH of 12. When titrating with NaOH the end point is the appearance of light and when titrating with HCl it is the extinguishing of the light.

A comparison of phenolphthalein and luminol by means of titrations with NaOH yielded the same end point for the two indicators,[11, 26] with a deviation of 0.63 parts/1000 for phenolphthalein and 1.25 parts/1000 for luminol. The visual type of titrator shown in FIGURE 4 was employed.

By superimposing potentiometric titration curves of HCl with NaOH, obtained both in the presence and in the absence of the indicator, considerable buffer action of the indicator was demonstrated, both before and after reaching the end point.

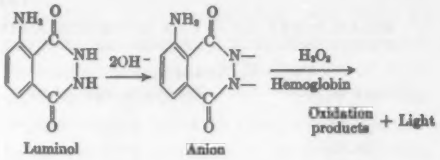

FIGURE 5. Behavior of luminol indicator when base is added.

In order to diminish buffer action, a second series of potentiometric titrations was carried out, using 1/138 of the luminol, 1/12 of the hemoglobin and 1/6 of the hydrogen peroxide employed in the previous set of titrations. In this second series HCl was used to titrate 30.00 ml. of 0.1 M NaOH containing 0.1 ml. of 5 per cent hemoglobin solution and 0.5 ml. of 35 per cent hydrogen peroxide. The HCl contained 10 mgm. of luminol per liter. The buffer action was materially decreased, and at values of pH below 6.3 it was completely eliminated. By adding the luminol to the HCl, a constant supply was insured. If all three indicator components had been added to the NaOH, light would have been given out at once and some component of the indicator might have been used up before reaching the end point.

The indicator was tested on two series of titrations, one using 30.00 ml. of 0.1 M NaOH and the other 30.00 ml. of 0.1 M NaOH

TABLE 3

TITRATION OF 0.1000 /M LEAD NITRATE WITH 0.1000 /M POTASSIUM CHROMATE USING 0.02 TO 0.08 GM. OF SILOXENE AT PH BETWEEN 1.9 AND 3.0

Chromate solution ml.	*Deviation from mean* ml.	*Chromate solution* ml.	*Deviation from mean* ml.
30.04	0.06	29.98	0.00
30.00	0.02	29.85	0.13
29.91	0.07	29.89	0.09
30.00	0.02	29.96	0.02
30.00	0.02	30.02	0.04
29.89	0.09	29.99	0.01
30.00	0.02	30.05	0.07
29.99	0.01	30.07	0.09
		29.98	0.04 Mean

TABLE 4

MILLILITERS OF 0.1 /M HYDROCHLORIC ACID-LUMINOL SOLUTION REQUIRED FOR PHOTOMETRIC TITRATION OF 30.00 ML. OF 0.1 /M SODIUM HYDROXIDE SOLUTION

Clear NaOH solution		NaOH solution containing 3 drops India ink	
Volume of HCl	*Deviation from mean*	*Volume of HCl*	*Deviation from mean*
ml.	ml.	ml.	ml.
28.75	0.04	28.80	0.00
28.82	0.03	28.85	0.05
28.85	0.06	28.80	0.00
28.75	0.04	28.80	0.00
28.80	0.01	28.80	0.00
28.72	0.07	28.80	0.00
28.80	0.01	28.79	0.01
28.80	0.01	28.78	0.02
28.79	0.03 Mean	28.80	0.01 Mean

containing three drops of India ink.[12,27] This solution was so dark that the use of an ordinary acid-base indicator would have been impossible. The multiplier photometer titrator was employed, the end point being the swift swing of the hand from a reading of about 0.06 microlumen down to zero. The results of these titrations are shown in TABLE 4. They yield, for the clear solution, an error of 1.0 parts/1000 and a deviation of 1.2 parts/1000, and for the dark solution, an error of 0.7 parts/1000 and a deviation of 0.3 parts/1000.

Conclusion

Chemiluminescent indicators were selected which gave good end points in oxidimetric, precipitation, and neutralization reactions carried out in solutions having sufficient color or turbidity to eliminate the use of ordinary redox indicators, or ordinary acid-base indicators.

References

1. WÖHLER, F. 1863. Ann. **127**: 263.
2. KIPPING, F. S. 1912. J. Chem. Soc. **101**: 2106.
3. HUCKEL, W. 1948. Anorganische Strukturchemie. F. Enke Verlag. Stuttgart, Germany.
4. KAUTSKY, H. 1943. Kolloid-Z. **102**: 1.
5. KAUTSKY, H. 1921. Z. anorg. Chem. **117**: 215.
6. KAUTSKY, H. 1952. Z. Naturforsch. **7B**: 174.
7. KAUTSKY, H. & E. GAUBATZ. 1930. Z. anorg. Chem. **191**: 384.
8. BOHM, J. & O. HASSEL. 1927. Z. anorg. Chem. **160**: 161.
9. KAUTSKY, H. 1938. Z. anorg. Chem. **236**: 127.
10. KENNY, F. & R. KURTZ. 1950. Anal. Chemi. **22**: 693.
11. KENNY, F. & R. KURTZ. 1951. Anal. Chemi. **23**: 382.
12. Photovolt Corp. Operating Instructions for Multiplier Photometer 520-A. New York.
13. KENNY, F. & R. KURTZ. 1953. Anal. Chemi. **25**: 1550.
14. HABER, F. & J. WEISS. 1934. Proc. Roy. Soc. (A) **147**: 332.
15. URI, N. 1952. Chem. Revs. **50**: 375.
16. HOLST, G. 1954. Chem. Revs, **54**: 176.
17. WATERS, W. A. 1946. Chemistry of Free Radicals. Clarendon Press. Oxford, England.
18. SCHALES, O. 1939. Ber. **72**: 167.
19. WEBER, K., A. REZEK & V. VOUK. 1942. Ber. **75**: 1141.
20. LEACH, S. J. 1954. Advances in Enzymology. Interscience. New York. **15**: 1.
21. WEBER, K. 1942. Ber. **75B**: 568.
22. BERNANOSE, A. 1950. Bull. soc. chim. France. **17**: 567.
23. BERNANOSE, A. 1951. Bull. soc. chim. France. **18**: 329.
24. SIMPSON, J. C. E. 1953. Condensed Pyridazine and Pyrazine Rings. Vol. 5. Chemistry of Heterocyclic Compounds. Interscience. New York.
25. DREW, H. D. K. 1939. Trans. Faraday Soc. **35**: 210.
26. KENNY, F. & R. KURTZ. 1951. Anal. Chemi. **23**: 339.
27. KENNY, F. & R. KURTZ. 1952. Anal. Chemi. **24**: 1218.

SOME GENERAL FEATURES OF THE PROCESSES OF CHEMILUMINESCENCE IN SOLUTION (INCLUDING VIOLANTHRONE)*

By RUSSELL B. KURTZ**

When an aromatic, fluorescent molecule such as anthracene absorbs a quantum of light, two π-electrons, are especially effected. In the singlet ground state their spins would be coupled and they might be regarded as being in an orbital of the entire molecule. In the triplet, activated state their spins would be parallel, with each uncoupled electron located in an independent orbital, on spatially separated areas of the molecule, centering around the two mesocarbons of the anthracene.[1] The two mesocarbons then become free-radical centers, and the activated molecule has diradical paramagnetism (a singlet state is also possible when activated).

The existence of a diradical is denied on the basis of magnetic and spectroscopic measurements.[3] An easy conversion, however, between activated singlet and triplet levels, with a second molecule participating would permit these arguments.

When molecular oxygen (itself a diradical) reacts with such a triplet-state molecule, or a dimer with free electron, chemical energy much less than the original light quantum absorbed is liberated, a transannular peroxide is formed and the spins of the two original π-electrons are permanently prevented from mutually coupling.

The application of heat energy to this peroxide, in amount slightly more than the chemical energy, reverses the process—the oxygen dissociates, leaving the two π-electrons free to couple and revert to singlet ground state, with emission of a quantum of light of energy much greater than the heat energy.[2,44]

In the case of anthracene, only a small proportion of the molecules emit light by oxygen dissociation, most of the peroxide forming anthraquinone.*** In the case of 9,10-diphenyl-anthracene, the energy of the oxygen-carbon bond is less, owing partially to higher resonance in the free-radicals and smaller energy-difference between oxidized and reduced valence structures. Ninety-five per cent of its oxygen dissociates at 180°C. with light evolution simultaneously. Rubrene photo-peroxide yields 75 per cent of its oxygen at 150°C. with evolution of light.

There exist symmetric molecules of an electronegativity such that their transannular peroxides dissociate at room temperature. Their energy of reaction with oxygen is thus very small (actually endothermic by 15 kcal.).[4] They add to or dissociate freely from oxygen, the addition, of course, occurring when in an activated state. Each reaction with oxygen locks up or liberates a quantum of light energy of 40 to 70 kcal.

An example is 1,4-dimethoxy-9,10-diphenyl-anthracene.[5,6,7] Its photoperoxide in solution emits a continuous weak glow for months at 20°C., yielding, after 40 days, 70 per cent of its oxygen. In less than an hour at 80°C., it completely dissociates with liberation of the light energy originally absorbed. This light energy came originally from absorbed light. But it may be supplied chemically, because a bright chemiluminescence results when dibenzaldiperoxide is added to its green-fluorescing solution in paraffin oil at 250°C. No hydrogens are oxidized off as in the case of luminol to produce radicals, thermal activation producing the same result.[40,41,42,43]

Nitrogen free-radicals do not react with

*This paper, illustrated with lantern slides, was the second of two papers presented at a meeting of the Section on May 4, 1954.

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***Two concurrent reactions often occur during chemiluminescence: (a) dissociation of oxygen (light emission) and; (b) nondissociation (destructive oxidation). Anthrahydroquinone is fluorescent [and chemilumine scent by (a)] although anthraquinone [the main auto-oxidation product by (b)] is non-fluorescent.[45]

oxygen as do carbon free-radicals, hence may be expected to add and dissociate oxygen freely, the additions mainly involving pairing and unpairing electron spins.

Evidently 1, 3-(p-Dimethylaminophenyl)-isobenzofurane[9] forms a nitrogen diradical since its type forms a transannular peroxide[10] and it gives a bright yellow chemiluminescence when its solution in 1,2,4-trichlorobenzene is treated with dibenzaldiperoxide at about 210°C. It probably dimerizes[9, 43] in two steps.

Luminol, an almost symmetric molecule, might be expected to have a particularly unstable transannular peroxide since both triplet state electrons would be on nitrogen free-radicals. Lucigenin or lophine transannular peroxides might be expected to be unstable, being nitrogen heterocycles.

Photoperoxides have actually been prepared in darkness by purely chemical means. Criegee[11] states that the transannular peroxide of 9,10-diphenyl-anthracene has been prepared from 9,10-bis-(hydroperoxy)-9,10-diphenyl-9,10-dihydro-anthracene and lead tetra-acetate. The light obtained when this "photoperoxide" is added to hot paraffin oil at 250°C. is genuine chemiluminescence.

In contrast to the previous nonaqueous chemiluminescences, those used as indicators occur in water solution. Most occur only in alkaline solution (siloxene only in acid solution) and then only when hydrogen peroxide or some generator of peroxide is present. Kautsky[12] added the purple product of luminol oxidation by hypochlorite to alkaline water and obtained chemiluminescence without hydrogen peroxide, but it seems to the author that generators of peroxide might be hydroxyl radicals generated from the oxidation of hydroxyl ions by the purple compound. The purple compound would be either a quinone or semiquinone. Other chemiluminescent substances such as lophine give a similar purple color[13] and could only be semiquinones since they possess only one oxidizable hydrogen. A number of aromatic free-radicals are purple, hence it may be assumed that formation of an aromatic free-radical is the first step in the chemiluminescence process. The first step in a diene addition of maleic anhydride to diphenyl-isobenzofurane is a purple-red semiaddition where one electron is free to give color.[14]

To explain the high energy (up to 75 kcal.) evolved in light emission, the union of two free-radicals is logical since they are both oxidized. They would be: (a) the luminol free-radical, and (b) the hydroxyl or hydroperoxyl free-radicals or radical-ions ($.0^-$ or $.0\overline{2}$). The latter are formed from decomposition of hydrogen peroxide in alkaline solution.

A possible mechanism for luminol chemiluminescence involves oxidizing off two hydrogens to give Kautsky's azo-aminophthalyl and subsequent reaction of this (purple) compound, not with water to hydrolyze, but with hydroxyl radical-ions ($.0^-$). Luminol has been used as a reagent for hydroxyl radicals.[15] The hydroxyl radicals might come from hydrogen peroxide or from oxidation of hydroxyl ions. After the purple compound had oxidized hydroxyl ions, it would become luminol again. Hydroxyl radical-ions, in attaching to luminol diradical (purple) could disrupt its valence structure into the triplet-state configuration, simultaneously restoring electrons to the oxidized luminol and uniting the oxygens to form a transient peroxide which would evolve oxygen and leave a triplet state, activated luminol molecule.

A change in the type of bond attaching oxygen to luminol would involve a strong, σ-type when the radical first attached, which would change to a weak π-type just before the triplet oxygen molecule dissociated off. The fact that oxygen will sometimes quench fluorescence is paralleled by the fact that photoperoxides liberate light by oxygen dissociation.[44]

It is impossible to activate by light absorption the fluorescence of luminol anion in alkaline solution, but it is possible to produce an activated valence configuration (chemically) in alkaline solution. Transient electronic readjustments in the ground-state anion would permit the same emission color in chemiluminescence as in fluorescence and the force opposing fluorescence activation would not oppose emission once the anion were activated chemically. Hence the assumption that the anion is the emitter. The oxidation state is identical in both anion and in luminol itself.

Luminol chemiluminescence has been the subject of innumerable papers since its discovery by Lommel about 1927.[16, 17, 18, 19, 20, 21, 22, 23] The name 5-amino-1,4-dihydroxy-phthalazine seems preferable[20] to 5-amino-2,3-dihydrophthalazine-1,4-dione on the basis of the aromatic character of the hetero-ring. Chemiluminescence is favored by substituents in the benzo-ring which augment fluorescence and render a compound more easily oxidizable (to form radical?), such as the hydroxyl, amino, methylamino, acetimido groups. Drew concludes[23] that electron donating groups, e.g. NH_2, OH, Cl, particularly at positions C_5 and C_8, increase luminescence. NO_2 has an opposite effect. In the hetero-ring both nitrogens must be unattached to substituent groups—the two hydrogens must be free to be oxidized off, permitting diradical formation. There is weak luminescence, however, when one nitrogen is substituted, showing a resemblance to lophine. There is no luminescence when both nitrogens are substituted. Increasing the number of rings does not increase chemiluminescence.[23] All cyclic hydrazides had at least a weak chemiluminescence, but none except the 5-diazonium compound exceeded that of luminol itself.[24, 25] Diazonium salts generate free radicals and are catalysts for bright chemiluminescence.[17] Noncyclic hydrazides which are fluorescent give some chemiluminescence[12] such as di-anthranilic hydrazide.

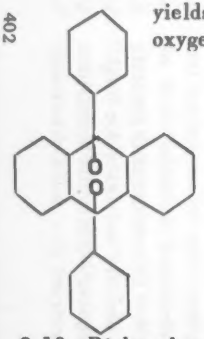
The brilliance of the light is the reciprocal of its duration. The quantum yield is about 0.2 to 0.5 per cent, that is, for every 1000 molecules of luminol oxidized to aminophthalic acid, two to five molecules emit a quantum of light.[19] The light-emitting reaction is thus inferior to the destructive reaction.*

Those reagents which generate free radicals from hydrogen peroxide[26, 28] also give chemiluminescence with luminol and hydrogen peroxide. If the reagent is a catalyst cyclically regenerated (such as complexes of Fe, Mn, Ni, Co, Cu, Os, Ru, Ce), hydroxyl ($.O^-$) and hydroperoxyl ($.O_2^-$) radicals will be formed, possibly according to the Haber and Weiss scheme.[27] If the reagent is not cyclically regenerated, as in the case of hypochlorite, diazonium, per-nitrite, NO_2, and ozone, a strong transient radical evolution gives a strong transient light. Other processes, such as auto-oxidation, coupled-oxidations (e.g. formaldehyde-H_2O_2) furnish free radicals and light. Oxygen is present in all these reactions, even when Kautsky's purple compound emits light in the absence of hydrogen peroxide.

Lucigenin (N,N′-dimethyl-biacridylium nitrate) requires hydrogen peroxide only (and an alkaline solution) to emit light. Catalysts do not affect the intensity of the light; hence free hydroxyl or hydroperoxyl radicals from the hydrogen peroxide do not take part. This does not mean that other types of radicals are absent. No satisfactory mechanism has been developed.[22] Even the emitting molecule is only assumed to be N-methyl-acridone because the color of the emitted light is blue,[13] similar to the fluorescence, and because N-methyl-acridone is the final oxidation product. A transient peroxide would accordingly be formed with N-methyl-acridone.* The simple ionic addition of ($O_2^=$) to lucigenin, followed by dissociation of O_2 from reduced lucigenin

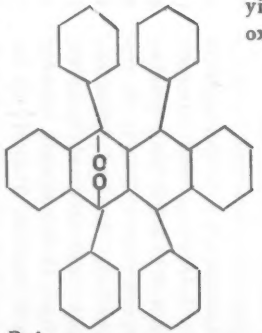
*See Footnote *** on Page 399.

DIAGRAM ILLUSTRATING ENDO-PEROXIDES, DIRADICALS, AND A DIMER OF A DIRADICAL



yields 95% of oxygen at 180°

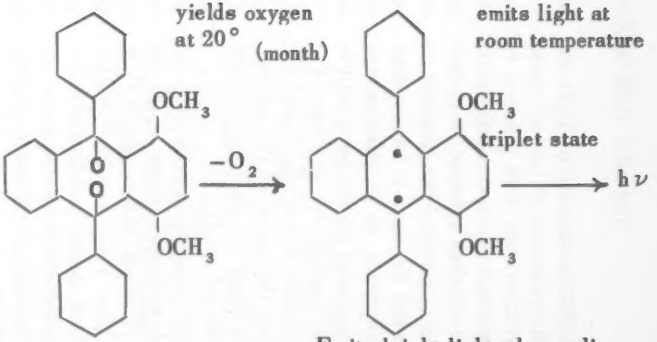
9,10 –Diphenyl-anthracene photo-peroxide



yields 75% of oxygen at 150°

Rubrene

Orange, fluorescent hydrocarbon
Colorless, non-fluorescent peroxide

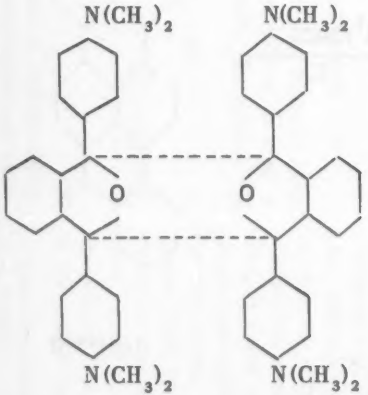


yields oxygen at 20° (month)

emits light at room temperature

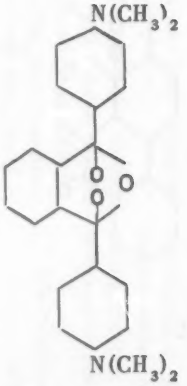
Emits bright light when dibenzaldiperoxide is added to its green-fluorescing solution at 250°

Chemiluminescent in parafin oil at 250°C. with dibenzaldiperoxide

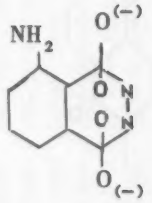


Dimer of 1,3–(Dimethylaminophenyl)–isobenzofurane

Bright yellow chemiluminescence at 250°

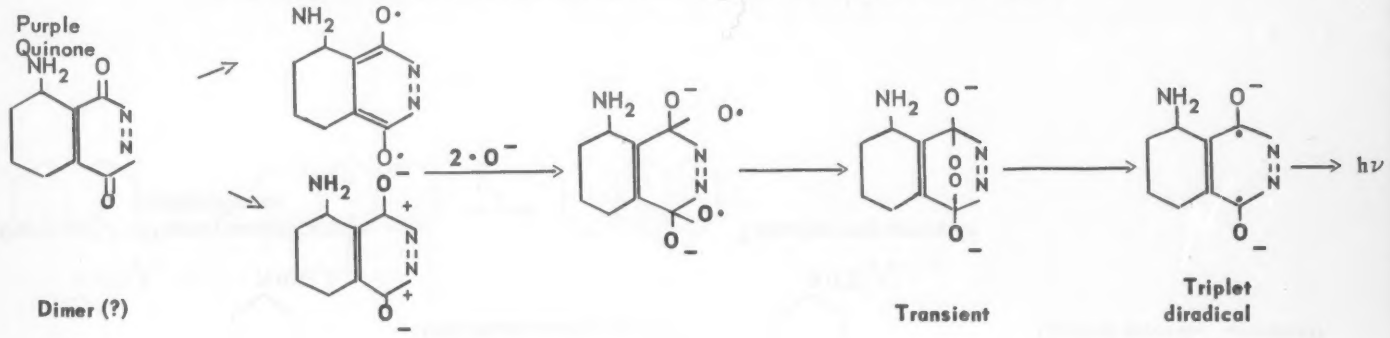


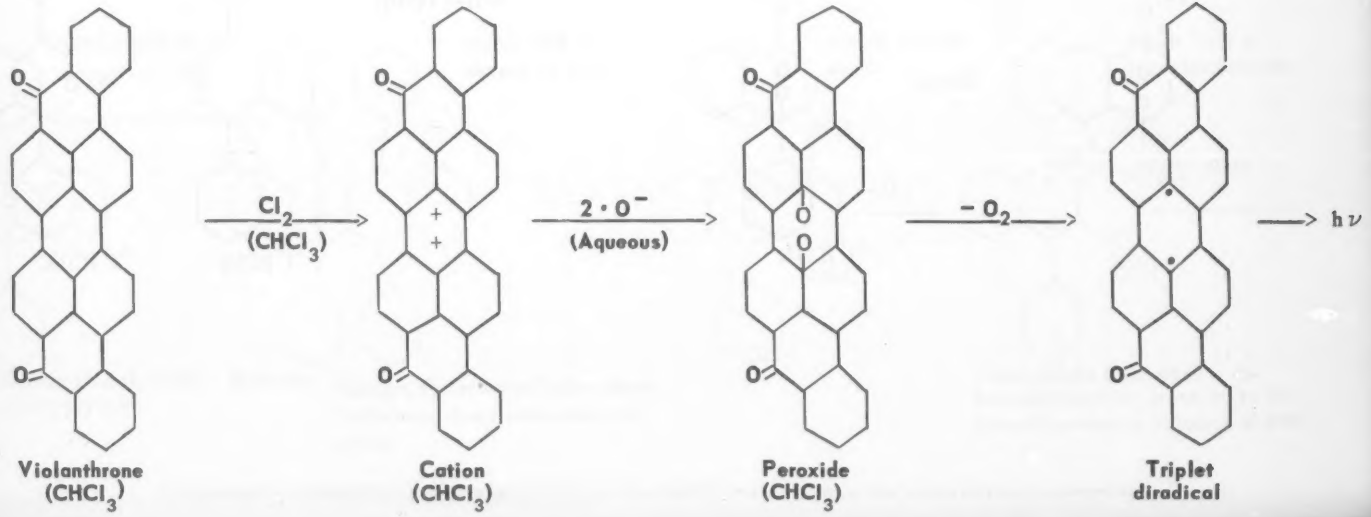
Transient endo-peroxide



Luminol peroxide (transient)

HYPOTHETICAL REACTION OF HYDROXYL RADICALS WITH LUMINOL FREE-RADICALS





(N,N′-dimethyl-biacridene) in an activated state would be the first mechanism to suggest itself (however, the fluorescence of N,N′-dimethyl-biacridene is greenish-yellow). The activated ethylene bond would be in a triplet state at the moment of dissociation. The lucigenin itself could be regarded as a "diradical"-di-cation, where the step involved in luminol radical formation has already been accomplished. Odd electron molecules may be either cations, anions, or neutral with a corresponding chemiluminescence mechanism if they are fluorescent. Lucigenin has been used as an acid-base indicator.[29]

Siloxene derivatives have been studied only by Kautsky.[30] They require neither hydrogen peroxide nor an alkaline solution, but only a strong oxidizing agent functioning in acid. Their reactions are typical of chain reactions. For example, exothermic decomposition of their molecules is initiated by light or by oxygen (or by oxidizing agents), and apparently it furnishes free radicals at certain points, which spread rapidly in every direction in the lamellar surface.[31] Hence, OSi-SiO bonds, Si-O bonds, and Si-H bonds resemble O-O bonds in furnishing free radicals.

Example 1. Reaction of siloxene with bromoform: the light from a burning match instantly colors the white surface of the siloxene violet-red.[32]

$$\text{Si-H} + \text{RX} \rightarrow \text{Si-X (colored)} + \text{RH}$$

The same reaction occurs in darkness when mere traces of oxygen suffice to start a vigorous reaction with bromoform.[32, 33]

$$\text{Si-H} + 0_2 \rightarrow \text{Si}\cdot$$

$$\text{Si}\cdot + \text{RX} \rightarrow \text{SiX} + \text{R}\cdot \qquad \text{R}\cdot + \text{Si-H} \rightarrow \text{RH} + \text{Si}\cdot$$

Chain

Example 2. Explosions of hydroxy-siloxenes: (a) red trihydroxysiloxene and especially black hexahydroxysiloxene shatter the containing vessels when traces of oxygen are admitted.[32, 34] The hexachlorosiloxene does not explode. This indicates oxidation of Si-Si bonds by OH groups or radicals. The hexahydroxysiloxene may explode upon illumination.[34, 35]

Example 3. Chemiluminescence of triaminosiloxene:[36] Only a trace of oxygen is required to make a sample under nitrogen emit a strong orange or red chemiluminescence. The energy is from an exothermal decomposition catalyzed by oxygen, and is transferred to fluorescent neighboring molecules which react as if adsorbed on the nonfluorescent, but energy-rich oxidizing structure of molecules.

Chemiluminescence of Violanthrone (Dibenzanthrone)

Violanthrone is a violet solid (solutions colloidal due to impurities) whose chloroform solution has a bright red fluorescence which disappears when dry hydrogen chloride gas (or chlorine) is passed in, the violanthrone forming a molecular addition compound. It was one of the first vat dyestuffs to be sold and has extreme resistance to oxidation and light. Brilliant red chemiluminescence may be obtained from this substance.* The orange-fluorescing solution in paraffin oil at 250°C. gives a bright orange-red light upon adding dibenzaldiperoxide, which is not catalyzed by iron phthalocyanine. Violanthrone is insoluble in water. Dissolved in a water-immiscible, inert solvent, such as chloroform, it would be attacked by alkaline hydrogen peroxide at the boundary between the two layers. The free-radical or cation formed from it by the action of chlorine which is also dissolved in the chloroform layer, would combine with peroxide anion or hydroxyl (or hydroperoxyl) free-radical in the water layer, forming a peroxide of

*Dichloroviolanthrone gives practically the same result.

violanthrone. Oxygen dissociation from this peroxide would leave an activated (triplet state) violanthrone molecule in the chloroform which would emit chemiluminescence. Weiss[37] in describing the formation of dibenzanthrone from benzanthrone says: "The observed color change on addition of oxidizing agent would correspond to the (halochromic) formation of the (benzanthrone)$^+$ odd ion. Under suitable conditions this dissociates into benzanthronyl radical and H^+. Dimerization of the former gives 2,2′-dibenzanthronyl, and dismutation yields benzanthrone and oxybenzanthrone." The color of the light corresponds to the fluorescence of the compounds used in the following demonstration: 0.5 gm. each of (a) Bz-1, Bz-1′-dibenzanthronyl, (b) 2,2′-dibenzanthronyl, and (c) dibenzanthrone (colloidal) are suspended separately in 30 ml. of chloroform. The fluorescence of solution (a) is bright green, (b) weak green, and (c) bright red. Chlorine gas from a cylinder is passed into each solution, destroying the fluorescence, but increasing the solubility. Ten to 15 ml. of each stock solution is put into separate 500-ml. flasks provided with glass inlet tubes almost touching the flask bottoms and provided with rubber outlet tubes to the hood. To each of the 500-ml. flasks is then added 30 ml. of 30 per cent hydrogen peroxide and 100 ml. of 3N sodium hydroxide. Chlorine is passed into each flask and the contents swirled rapidly. The chemiluminescence is as follows: (a) bright green, (b) bright orange, and (c) brilliant red, the light being sufficient to illuminate the front of a lecture room.

The inertness of the fluorescing dyes (a) and (c) under unusually strong oxidizing conditions is shown by the fact that the colors and fluorescences are unchanged after the reaction* even though only a small amount of dye was present originally. The radical or polar compound resumes normalcy (reduced) after emitting. In other chemiluminescent reactions (luminol) the emitting molecule is not so stable to oxidation. No light is emitted in the absence of a base, such as sodium hydroxide, pyridine, or quinoline.

Chlorine gas, alone, gives a red chemiluminescence when passed into alkaline hydrogen peroxide[38, 39] but the increased intensity, on adding a little chloroform solution of violanthrone is very striking. Pyridine may be used in a single liquid-phase reaction. To a strongly fluorescing dibenzanthrone solution in pyridine, 1/20 of its volume of perhydrol is added, then some pyridine solution of DuPont "Dactin" (dichlorodimethylhydantoin). A bright red light results. Chlorine gas (dry) is bubbled through a solution of dibenzanthrone in dry pyridine containing several drops of 90 per cent hydrogen peroxide. In the vicinity of each bubble appears a bright red light. In another experiment, 10 ml. of anhydrous chloroform is saturated with hydrogen peroxide by shaking it with five drops of 90 per cent hydrogen peroxide. Add 1 ml. of a chloroform solution of dibenzanthrone which has been saturated with chlorine gas. No chemiluminescence results, but upon adding several drops of dry pyridine, a very bright red chemiluminescence appears, although only a very little water is present. If a pyridine solution of dibenzanthrone containing 1/10 of its volume of perhydrol is treated with sodium hypochlorite, only a transient flash results. Chloranil or hemin give no light. Only pyridine- or chloroform-soluble oxidizing agents are effective. Substituted hydrogen peroxides, *e. g.* t-butyl, gave no light.

The removal of an electron from dibenzanthrone would leave an odd cation dissolved in chloroform. The H^+ would not dissociate leaving a neutral radical because H^+ is not soluble in chloroform (dielectric constant). But the large cation is soluble in chloroform. Hence, the chloroform pre-

*Chloro-violanthrones are also red-fluorescent and red-chemiluminescent.

serves the dibenzanthrone cation, and it is this cation which reacts with the free-radical-anion (hydroxyl or hydroperoxyl radical) to form a neutral, dissociable peroxide. The neutral, original dibenzanthrone (in triplet state with valences distorted to a diradical configuration) would be regenerated after oxygen dissociation.

References

1. LEWIS, G. N. & M. KASHA. 1944. J. Am. Chem. Soc. **66**: 2112.
2. AUDUBERT, R. & C. RACZ. 1943. Bull. soc. chim. France. **10**: 380.
3. ETIENNE, A. 1949. In Traité de Chimie organique. V. Grignard Ed. **17**: 1307. Masson. Paris.
4. ETIENNE, A. 1949. In Traité de Chimie organique. V. Grignard Ed. **17**: 1304. Masson. Paris.
5. ETIENNE, A. 1949. In Traité de Chimie organique. V. Grignard Ed. **17**: 1308. Masson. Paris.
6. DUFRAISSE, C. & L. VELLUZ. 1942. Bull. soc. chim. France. **9**: 171.
7. DUFRAISSE, C. & L. VELLUZ. 1939. Compt. rend. **209**: 516.
8. ETIENNE, A. 1949. In Traite de Chimie organique. V. Grignard Ed. **17**: 1315. Masson. Paris.
9. GYOT, A. & A. HALLER. 1910. Ann. de chimie. **19**: 323.
10. DUFRAISSE, C. & S. ECARY. 1946. Compt. rend. **223**: 735.
11. CRIEGEE, R. 1952. In Methoden der Organischen Chemie. Houben-Weyl Ed. 4th ed. **8**: 61. Georg T. Verlag. Stuttgart, Germany.
12. KAUTSKY, H. & K. H. KAISER. 1950. Z. Naturforsch. **5B**: 353.
13. KAUTSKY, H. & K. H. KAISER. 1943. Naturwissenschaften. **31**: 506.
14. ADAMS, R. 1940. J. Am. Chem. Soc. **62**: 2038.
15. EVANS, M. G. & J. H. BAXENDALE. 1947. The labile molecule. Trans. Faraday Soc. **43**: 221.
16. BERNANOSE, A. 1950. Bull. soc. chim. France. **17**: 567.
17. BERNANOSE, A. 1951. Bull. soc. chim. France. **18**: 329.
18. BREMER, T. 1947. Bull. soc. chim. Belges. **56**: 269.
19. BREMER, T. 1953. Bull. soc. chim. Belges. **62**: 569.
20. SIMPSON, J. C. E. 1953. Condensed Pyridazine and Pyrazine Rings. Interscience. New York.
21. VAUGHAN, W. R. 1948. Chem. Revs. **43**: 490.
22. ANDERSON, R. S. 1948. Ann. N. Y. Acad. Sci. **49**: 337.
23. DREW, H. D. K. 1939. Trans. Faraday Soc. **35**: 210.
24. WEGLER, R. 1937. J. prakt. Chem. **148**: 135.
25. DREW, H. D. K. & R. F. GARWOOD. 1937. J. Chem. Soc. : 1841.
26. URI, N. 1952. Chem. Revs. **50**: 375.
27. HABER, F. & J. WEISS. 1934. Proc. Roy. Soc. (A) **147**: 332.
28. WATERS, W. A. 1946. Chemistry of Free Radicals. Clarendon Press. Oxford, England.
29. ERDEY, L. 1953. Hung. Acta Chim. **3**: 81.
30. KAUTSKY, H. 1952. Z. Naturforsch. **7B**: 174.
31. KAUTSKY, H. 1943. Kolloid-Z. **102**: 13-14.
32. KAUTSKY, H. 1943. Kolloid-Z. **102**: 9.
33. KAUTSKY, H. & H. THIELE. 1925. Z. anorg. Chem. **144**: 213.
34. KAUTSKY, H. & H. THIELE. 1928. Z. anorg. Chem. **173**: 123.
35. HUCKEL, W. 1948. Anorganische Strukturchemie : 929. F. Enke Verlag. Stuttgart, Germany.
36. KAUTSKY, H. & G. HERZBERG. 1924. Z. anorg. Chem. **139**: 143.
37. WEISS, J. 1946. Trans. Faraday Soc. **42**: 119.
38. GROH, P. 1938. Bull. soc. chim. France. **5**: 13.
39. GROH, P. & A. KIRRMANN. 1942. Compt. rend. **215**: 275.
40. SCHLENK, W. & E. BERGMANN. 1928. Lieb. Annal. **463**: 179.
41. INGOLD, C. K. & P. G. MARSHALL. 1926. J. Chem. Soc. : 3080.
42. SCHOENBERG, A., A. F. A. ISMAIL & W. ASKER. 1946. J. Chem. Soc. : 442.
43. SCHOENBERG, A. *et al.* 1948. J. Chem. Soc. : 2127.
44. EYRING, H. *et al.* 1954. Kinetic Basis of Molecular Biology : 166. Wiley, New York, N. Y.
45. ETIENNE, A. & Y. FELLION. 1954. Compt. rend. **238**: 1430.

SECTION OF BIOLOGY

THE FINE STRUCTURE OF *TOKOPHRYA INFUSIONUM* WITH EMPHASIS ON THE FEEDING MECHANISM*

By MARIA A. RUDZINSKA AND KEITH R. PORTER**

*Tokophrya infusionum**** has been used for several years in studies examining the influence of food on the life span and reproduction rate of this protozoan.[1,2,3,4] During this work, observations made on single individuals suggested that this species might be especially useful for detailed studies on physiological and structural changes associated with aging. In consequence of this suggestion, a study of the structural aspects of this problem is now being made by means of electron microscopy. An analysis of many thin sections has already shown that valuable information can be gained by the use of the electron microscope in the study of the fine structure of this protozoan.[5,6]

Tokophrya infusionum, used for this study, is a small, sessile, fresh-water protozoan, 17 to 50 μ in diameter. It belongs to the class (or order[7]) Suctoria, a group of protozoa possessing highly specialized functions and correspondingly complicated body structure. The most characteristic features of the whole group are to be found in the manner of feeding and the mode of reproduction.

The majority of Suctoria feed on living ciliates by sucking the contents from the ciliates through long, slender tentacles. The organism is sessile in the adult form and is attached to the substrate by a stalk terminating in a foot or disc. The attachment to the substrate provided by the disc is surprisingly strong; for example, one *Tokophrya* may hold in its tentacles, at one time, as many as ten *Tetrahymena pyriformis*,[8] all struggling to escape, without itself being torn from the substrate. This suggests that the attaching disc must achieve a very intimate and secure contact with the supporting surface. The structural details of the disc are not evident with the light microscope for the reason that they are too fine, but with the electron microscope considerable information is made available. For such electron microscope studies the *Tokophrya* were grown on formvar-coated grids or coverslips, then fixed in vapors of 2 per cent OsO_4, washed in distilled water, and dried.[9,10] The discs, prepared in this way and viewed with the electron microscope, are found to be made up of a felt or meshwork of innumerable fine fibrils (each about 150 μ thick) closely applied to the substrate. At scattered places in this meshwork these fibrils appear to show a fine periodicity of about 120 Å. Also, the fine fibrils are occasionally twisted to form slender ropes and, in this respect, they are quite similar to formations of cellulose in *Acetobacterium xylinum*.[11]

As mentioned above, the attaching disc keeps *Tokophrya* firmly in place while it captures and feeds on the motile prey which comes by chance into contact with the tips of the tentacles. Shortly after capture the prey becomes motionless and in a few seconds its cytoplasm begins to flow through the tentacles into the body of *Tokophrya*. This unusual way of feeding has attracted and still attracts the attention of students of protozoa. Obviously one of the main difficulties in arriving at a better understanding of the phenomenon is the

* This paper, illustrated with lantern slides, was the first of three papers presented at a meeting of the Section on May 10, 1954. The research reported herein was supported by a grant from the National Heart Institute, U.S. Public Health Service.

** Rockefeller Institute for Medical Research, New York, N.Y.

*** The culture of *T. infusionum* was generously supplied by Doctor Daniel M. Lilly in 1948. The first studies on *Tokophrya* were started in 1939 with Doctor Henryk Raabe in Poland.

very small (approx. 1 μ) diameter of the tentacle. As in the case of the foot, its structure is not resolved by light microscopy. The major questions to be answered are: (1) what mechanism does the *Tokophrya* use to capture its prey?; (2) what mechanism, if any, is present which might account for the passage of cell contents from prey to predator?; and (3) what is the fate of the ingested food?

In the capture of food it is known that the knob is the only part of the tentacle to become attached to the prey. It would seem that the knob is either sticky or supplied with small hooks or suction cups. In this respect, therefore, the fine structure of the tip is of some interest. Under the light microscope it appears simply as a thickened end on the tentacle. In the electron microscope, however, a fairly complex structure is evident. First the tentacle is covered by a sheath or pellicle which seems, in places, to be folded. Within the sheath, there is a system of fibrous elements which are arranged lengthwise along the tentacle. The tip or knob of the tentacle consists of a tuft of papillae which probably are continuous with the longitudinal fibers coming up through the tentacle. The pellicular sheath ends at the base of the knob and leaves the papillae free. Each of the papillae is covered by a substance which appears amorphous and is, presumably, the adhesive material for capturing and holding the prey.

Even though the prey becomes motionless upon contact with the tentacle, the protoplasm appears to retain its living characteristics, as evidenced by the continued functioning of the contractile vacuole. There is, then, a sort of paralysis which, perhaps, results from an injection of a substance into the prey by *Tokophrya* or possibly from some subtle change in the cortex of the prey initiated by contact with the tentacle tip. Some indication of a change in the cytoplasm at the site of tentacle attachment to the prey is apparent in thin sections although, from fixed material, it is obviously difficult to define its nature. The suggestion from the image is that the cytoplasm in the region of attachment is markedly solated.

The mechanism involved in the passage of the prey cytoplasm down the tentacle is interesting but difficult to understand. One of the major questions is whether the tentacle plays an active or passive part in this process. To help answer this question, a more detailed analysis of the structure of the tentacle was undertaken. In this study, *Tokophrya* was fixed in 1 per cent OsO_4 at a pH of 8.5,[12] dehydrated, embedded in *n*-butyl methacrylate, and sectioned with a microtome designed especially for thin sectioning by Porter and Blum.[13] Cross sections of the tentacle which were obtained showed the structure to be a tube enclosed in a pellicular sheath and the plasma membrane. Within the wall of the tube and running lengthwise along the tentacle there are over 40 very fine filaments (150-180 Å thick). These are embedded in a matrix material which surrounds the lumen of the tentacle. It is of interest to point out that filaments of the same thickness have been found in cilia of metazoans (Fawcett and Porter[14]).

In some cross sections two, four, or more tubes were found in a single tentacle. Thus it seems that the tentacle is a single tube only at its base, whence it divides into two tubes, each of which divides again. All the tubes, whether occurring singly or in multiples, have the same structure with filaments in the wall of the lumen.

The presence of numerous fine, longitudinal filaments provides the tentacle with what may be assumed to be contractile elements which may be responsible for the shortening that the tentacle undergoes during feeding. This shortening is probably related, as well, to the folds which appear in the pellicular sheath covering the ten-

tacle. Such folds have been observed in tentacles of living Suctoria during feeding.[15,16,17] It is conceivable that the filaments represent the structural basis for peristaltic waves of contraction which, in moving down the tentacle, would carry the food from the prey to *Tokophrya*.[15] Other explanations for the passage of food through the tentacles have postulated a difference in pressure between the two organisms.[18,19]

Certain structures of the tentacle, such as the wall of the lumen with the filaments, continue into the cytoplasm of *Tokophrya*. These structures obviously serve to guide the food particles into the deeper parts of the organism, as may be seen in living individuals with the light microscope.

The third problem connected with the mechanism of feeding is the fate of the ingested cytoplasm. The question is whether the cytoplasm of the prey is taken up into food vacuoles upon entering *Tokophrya*, or whether it simply mixes with the cytoplasm of the predator. The answer seems to be quite apparent in thin sections. It was found that a feeding *Tokophrya* is filled with distinct vacuoles containing mitochondria and lipids. Outside the vacuoles it is possible to identify mitochondria suspended in the matrix of *Tokophrya* and also elements of the endoplasmic reticulum. This latter system is a complex of vesicles and canaliculi, which was not evident from light microscopy but was first observed by means of electron microscopy in cultured mammalian and avian tissue cells by Porter.[9,10]

The mitochondria here, and in fact in all Protozoa, are similar to those described by Palade[20] in higher forms, with a single exception. In the mammalian mitochondria the contained structures are in the nature of folds or ridges extending from the internal membrane. In *Tokophrya* and *Tetrahymena* these same structures are finger-like processes or microvilli. Both types of mitochondria, those inside the vacuoles and those in the matrix, look quite similar and yet show distinguishing differences. The mitochondria enclosed in vacuoles are larger, about 600 mμ in diameter, while those outside the vacuoles are about 400 mμ in diameter. In the former, the microvilli are thinner and more closely packed than those in the latter. It is easy to identify those within the vacuoles as derived from *Tetrahymena* because in thin sections of this organism the same type of mitochondria can be seen. In this way, evidence was given that the ingested food is enclosed in food vacuoles and probably digested there.

The other characteristic feature of Suctoria is their mode of reproduction. *Tokophrya* reproduces by endogenous budding, forming a succession of embryos each of which contains only a small part of the parent macronucleus. The embryo, which is ciliated, after leaving the parent's body, swims for several minutes to several hours, and then undergoes metamorphosis, changing to the sessile form with tentacles. The parent organism continues to reproduce for a period of several days to several weeks. During this time it ages and finally dies. This feature, quite unusual among protozoa, makes *Tokophrya* a very favorable material for the study of physiological and structural changes associated with aging.

The reproduction of *Tokophrya* involves many structural components of the adult organism and brings to one's attention several important phenomena. Among these the form and behavior of the macronucleus are of general interest.

It is reasonable to expect that a study of the macronucleus at these levels of resolution might provide some clues to its functioning. The classical concept confined its activity in the organism to the somatic or metabolic functions. In the last few years Sonneborn,[21] from his studies on *Paramecium aurelia*, has proposed that the macronucleus is composed of subnuclei and that factors in the macronucleus find expression in the phenotype of the cell. Grell,

who described the polyploid character of the suctorian macronucleus, goes even further. He states that some observations favor the concept that the macronucleus alone is responsible for the phenotype, the micronucleus being "inert."[22] The observation that several ciliates have no micronucleus seems to support this latter view.

Thin sections of the macronucleus show that it is composed of dense chromatin bodies and a relatively homogeneous matrix. Around the macronucleus there is a membrane which shows evidence of perforation. The dense bodies are not products of the osmium fixation, for they are large enough to be clearly seen in phase-contrast microscopy of living organisms. They appear, moreover, as the Feulgen-positive bodies in the macronucleus of fixed and stained organisms.

Reference to these bodies as chromatin bodies is therefore not without foundation, and further support comes from an examina- of their fine structure. At high magnifications they appear as a fine sponge-work of dense material without a limiting membrane, and this same appearance characterizes the chromosomes of higher organisms.[23]

References

1. RUDZINSKA, M. A. 1951. The influence of the amount of food on the reproduction rate and longevity of a Suctorian (*Tokophrya infusionum*). Science. **113**: 10-11.
2. RUDZINSKA, M. A. 1952. Overfeeding and life span in *Tokophrya infusionum*. J. Gerontol. **7**: 544-548.
3. RUDZINSKA, M. A. 1953. Giant individuals and vigor of populations in *Tokophrya infusionum*. Ann. N.Y. Acad. Sci. **56**: 1087-1090.
4. LILLY, D. M. 1953. The nutrition of carnivorous protozoa. Ann. N.Y. Acad. Sci. **56**: 910-920.
5. RUDZINSKA, M. A. & K. R. PORTER, 1953. An electron microscope study of a protozoan, *Tokophrya infusionum*. Anat. Record **115**: 363-364.
6. RUDZINSKA, M. A. & K. R. PORTER. 1953. Submicroscopic morphology of structures involved in the feeding of *Tokophrya infusionum*. Proc. Soc. Protozoologists, **4**: 9.
7. FAURE-FREMIET, E. 1950. Morphologie comparée et systématique des Ciliés. Bull. Soc. Zool. France. **75**: 109-122.
8. CORLISS, J. O. 1952. Comparative studies on holotrichous ciliates in the *Colpidium-Glaucoma - Leucophrys - Tetrahymena* group. Trans. Am. Microscop. Soc. **71**: 159-184.
9. PORTER, K. R., A. CLAUDE & F. FULLAM. 1945. A study of tissue culture cells by electron microscopy. Methods and preliminary observations. J. Exptl. Med. **81**: 233-246.
10. PORTER, K. R. 1953. Observations on a submicroscopic basophilic component of cytoplasm. J. Exptl. Med. **97**: 727-750.
11. MUHLETHALER, K. 1949. The structure of bacterial cellulose. Biochim. et Biophys. Acta. **3**: 527-535.
12. PALADE, G. E. 1952. A study of fixation for electron microscopy. J. Exptl. Med. **95**: 285-298.
13. PORTER, K. R. & J. BLUM. 1953. A study of microtomy for electron microscopy. Anat. Record. **117**: 685-712.
14. FAWCETT, D. W. & K. R. PORTER. 1954. A study of the fine structure of ciliated epithelia. J. Morphol. **94**: 221-282.
15. COLLIN, B. 1912. Etude monographique sur les Acinétiens. II. Morphologie, physiologie, systematique. Arch. Zool. exptl. et gén. **51**: 1-457.
16. GUILCHER, Y. & J. DRAGESCO. 1950. Sur la structure et le fonctionnement des tentacules d'Acinétiens. Microscopie. **2**: 17-25.
17. PENARD, E. 1920. Etude sur les Tentaculifères. Mém. Soc. Phys. Hist. Genève. **39**: 131-229.
18. KAHL, A. 1931. Über die verwandtschaftlichen Beziehungen der Suctorien zu den prostomen Infusorien. Arch. Protistenk. **73**: 423-481.
19. KITCHING, J. A. 1952. Observations on the mechanism of feeding in the suctorian *Podophrya*. J. Exptl. Biol. **29**: 255-266.
20. PALADE, G. E. 1953. An electron microscope study of the mitochondrial structure. J. Histochem. & Cytochem. **1**: 188-211.
21. SONNEBORN, T. M. 1947. Recent advances in the genetics of *Paramecium* and *Euplotes*. Advances in Genetics. **1**: 263-358.
22. GRELL, K. G. 1953. Die Struktur des Makronucleus von *Tokophrya*. Arch. Protistenk. **98**: 466-468.
23. PORTER, K. R. 1953. Changes in cytoplasmic fine structure accompanying mitosis in rat sarcoma cells. J. Applied Phys. **24**: 1423.

RELATIVE AND LIMITING CONCENTRATIONS OF MAJOR MINERAL CONSTITUENTS FOR THE GROWTH OF ALGAL FLAGELLATES*

By LUIGI PROVASOLI, JOHN J. A. McLAUGHLIN, AND IRMA J. PINTNER**

Introduction

The object of the work reported here has been to find out how closely the mineral requirements of fresh-water and marine microorganisms reflect the composition of natural waters. The present paper describes orientation experiments intended to gauge the relative importance of total concentrations and of the ratios between major mineral constituents in supporting the growth of several fresh-water, brackish, and marine phytoflagellates. The organic factors required by these organisms will be described elsewhere.

Rodhe,[1] after comprehensive analysis of 180 Swedish lakes, concludes that most fresh waters are of a calcareous-carbonate-rich type, and that lake waters differ mainly in respect to total solids; the ratio of the major ions (Na^+, K^+, Mg^{++}, Ca^{++}, Cl^-, HCO_3^-, $SO_4^=$, and SiO_2^-) is almost constant. This simplification, if generally valid, reduces natural waters to two main types, and provides a simple basis of comparison between fresh water and sea water. (Brackish waters represent an intermediate type.) The principal differences between the two types of water (TABLE 1) are in: (1) total solids, (2) ratio of monovalent to divalent ions, (3) quantitatively predominant cations and anions, and (4) the ratio Mg/Ca.

The experiments were so designed as to vary the salinity or total solid content, the monovalent/divalent ratios (M/D), and the Ca/Mg ratios in culture media, thereby permitting an evaluation of the relative or absolute importance of these factors to growth. How specialized are these organisms in respect to the inorganic constituents of their typical environments? Such information may be of practical value, since nonprecipitating media for marine organisms could be better formulated if these organisms withstood substitution of the more soluble monovalent salts for the bulk of the less soluble divalent salts.

*This paper, illustrated with lantern slides, was the second of three papers presented at a meeting of the Section on May 10, 1954.

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TABLE 1

PRINCIPAL DIFFERENCES IN THE CONSTITUTION OF FRESH WATER AND SEA WATER

	Fresh water	*Sea water*
Total solids (ppm.)	50-500	30,-38,000
Ratio $\frac{\text{Monovalent}}{\text{Divalent}}$	< 1.5; usually 0.3	6.5
Predominating cations	Ca	Na, Mg
Predominating anions	HCO_3	Cl
Ca/Mg	2:1	1:3

Experimental Methods

The basal media (TABLES 2 and 3) contain nitrate, phosphate, a metal chelator (in media for *Synura* sp.[3] and *Fragilaria*); trace elements, a pH buffer usually, vitamins; and, when required, other organic nutrients (amino acids for *Synura* sp., *Rhodomonas*, and *Syracosphaera*; and hydrolyzed yeast nucleic acid for *Syracosphaera*.). To this

TABLE 2

MARINE BASAL MEDIUM

KNO_3	0.03 g.	Boron (as H_3BO_3)	2.0 mg.
K_2HPO_4	6.0 mg.	Fe (as Cl^-)	0.04 mg.
KCl	0.4 g.	Mn (as Cl^-)	0.12 mg.
$Na_2SO_4 \cdot 10H_2O$	3.4 g.	Cu (as Cl^-)	0.00012 mg.
B-Vitamin mixture[2]	0.2 ml.	Co (as Cl^-)	0.00015 mg.
B_{12}	0.1γ	Zn (as Cl^-)	0.015 mg.
Tris(-hydroxy-methyl)-amino-methane	1.0 g.	H_2O to 1000 ml. pH 7.2 -7.4 Salinity = 2.0 g.‰	

medium were added, as variables, Na, Mg, K and Ca as chlorides. In sea-water experiments (TABLES 2 and 4), K and SO_4 were included in the basal medium and were therefore constant; salinity calculated as the sums of the anhydrous salts was varied by addition of NaCl. Nine different solutions were compounded so that the sum of the

TABLE 3

FRAGILARIA BASAL MEDIUM

H_2O to	1000 ml.	Mn (as Cl^-)	8.0 mg.
$Na_2SiO_3 \cdot 9H_2O$	0.3 g.	Mo (as Na salt)	0.2 mg.
NH_4NO_3	0.05 g.	Cu (as Cl^-)	0.03 mg.
*"Versen-ol"	0.05 g.	Co (as Cl−)	0.3 mg.
Fe (as Cl^-)	1.0 mg.	K glycero-phosphate	4.0 mg.
Zn (as Cl^-)	1.0 mg.	Tris-(hydroxy-methyl)-amino-methane**	0.5 g.
		pH = 7.0-7.2	

*"Versen-Ol," a chelating agent, is the 3Na salt of *N*-hydroxyethylethylene-diamine triacetic acid, and was obtained from the Bersworth Chemical Co. The concentration shown was calculated as the free acid.
**pH buffer

weights of Ca + Mg (calculated as metals rather than salts)* was kept a constant, but the ratio Ca/Mg was varied as follows: 24:1, 12:1, 6:1, 3:1, 1:1, 1:3, 1:6, 1:12, and 1:24.

In fresh-water media, the basal medium (TABLE 3) had a constant concentration of Na and a relatively small K concentration. Changes in total solids (TABLE 5) were obtained by varying K and the amount of the various Ca/Mg mixtures (as chlorides).

Black circles in TABLES 6, 7, 8, and 9 stand for growth throughout the nine solutions of various Ca/Mg ratios. Decreasing fractions of the circles indicate the proportionately decreasing number of the nine separate solutions (giving different Ca/Mg ratios) allowing growth. For *Fragilaria* and *Synura*, a decreased amount of growth is indicated by gray circles.

*The concentration of $MgCl_2$ solutions was determined by titration of chloride.

TABLE 4

RHODOMONAS EXPERIMENT

Salinity (in g. ‰) in rectangle enclosed in double lines

$Na_2SO_4 + KCl$ in basal medium	2	2	2	Corresponding $\frac{Na+K}{Mg+Ca}$ ratios		
$CaCl_2 + MgCl_2$ \ NaCl	9	18	36			
0.4	11.4	20.4	38.4	34	62	118
1.0	12.0	21.0	39.0	12	24	48
2.1	13.1	22.1	40.1	6	12	24
4.2	15.2	24.2	42.2	3	6	12

Sea Water: salinity 34.00‰; $\frac{Na + K}{Mg + Ca}$ = M/D ratio = 6.5.

Organisms

Fragilaria capucina (North Carolina) and *Synura* sp. (Long Island) were isolated from dilute fresh-waters (50-80 p.p.m. total solids). *Peridinium balticum* and *Exuviella cassubica* (both from Woods Hole, Mass.) were isolated from brackish pond waters of 4 to 6 parts per thousand salinity, *Syracosphaera carterae* was purified from bacterized clonal cultures isolated by E. Fagerland from an artificial oyster pond of ferti-

TABLE 5

DESIGN OF *FRAGILARIA* EXPERIMENT

Na	43		43		43	
K \ Mg + Ca	2		10		50	
	TS	M/D	TS	M/D	TS	M/D
5.0	190	10.0	210	12.0	290	21.0
22.5	250	2.0	270	2.4	345	4.2
45.0	330	1.0	345	1.2	425	2.1
90.0	480	0.5	495	0.6	570	1.0
180.0	780	0.25	795	0.3	870	0.52

TS = total solids in p.p.m., M/D = monovalent/divalent ratio.

TABLE 6

SYNURA SP.

Results according to, (A) increasing monovalent/divalent ratios (M/D), and (B) decreasing total solids (TS) in p.p.m. G = growth (see "experimental methods").

A			B		
M/D	T.S.	G	T.S.	M/D	G
0.6	143	◔	218	2.0	◔
1.0	161	◔	171	4.0	◑
1.3	96	◑	161	1.0	◔
1.8	114	◑	143	0.6	◔
2.0	218	◔	138	10.0	◕
3.3	63	●	114	1.8	◑
4.0	171	◑	96	1.3	◑
5.0	81	◕	81	5.0	◕
10.0	138	◕	63	3.3	●

Circles containing dots indicate less growth

lized sea water (salinity 30 parts per thousand in Norway; *Rhodomonas lens* was purified from bacterized clonal cultures isolated by R. Lasker from the Gulf Stream off Miami, Fla. All cultures were bacteria-free. The culture vessels were screw-capped tubes provided with continuous fluorescent lighting. The cultural methods were as previously described.[4]

Analysis of Results

(A) Synura sp. Ability to grow at different Ca/Mg ratios correlates with total solid concentration (TABLE 6, right-hand column): low concentrations (60 to 180 p.p.m.) are preferred. The M/D ratios, however, are also significant. When the results are tabulated according to an increasing M/D ratio (TABLE 6, left-hand column) it is seen that ratios below 1.3 and above 5 restrict growth in general and also restrict the range of favorable Ca/Mg ratios even at favorable total solids concentrations (for example: total solids 138, 143, 161; this Ca-Mg-total solid interaction is evident also in TABLE 7 where the diagonals represent similar values of total solids but great variations in M/D ratios). In conclusion, the organism grows better at: *(a)* low total solid concentration (60 to 100 p.p.m.); *(b)* in the presence of more monovalent than divalent metals (M/D ratios = 2 to 5 and probably higher); and *(c)* throughout the whole range of Ca/Mg ratios when the two previous conditions are met. Growth is still observed at higher total solid concentration but then only at narrow Ca/Mg/K ratios.

(B) Fragilaria capucina. Ability to grow at different Ca/Mg ratios correlates with M/D ratios: the optimal zone is between 0.25 and 0.5. Even then the ratio Mg/Ca = 24:1 allows only slight growth. In general, as the ratio M/D increases (*i. e.*, more monovalent ions), higher Ca/Mg ratios are needed (*i.e.*, more Ca) and Ca can be considered

TABLE 7

SYNURA SP.

Amounts of Na, K, Ca, Mg are expressed in p.p.m. In central rectangles, the numbers at the left of the circles represent total solids values; the numbers at the right, the M/D ratio

Na	15	15	15
K / Ca+Mg	5	15	45
6.4	63 ● 3.3	81 ◕ 5.0	138 ◕ 10.0
16	96 ◑ 1.5	114 ◑ 1.8	171 ◑ 4.0
32	143 ◔ 0.6	161 ◔ 1.0	218 ◔ 2.0

Circles containing dots indicate less growth

TABLE 8

FRAGILARIA CAPUCINA

M/D = monovalent/divalent ratio; TS = total solids in p.p.m.; G = growth; Gray represents less growth.

M. D.	T.S.	G.	M. D.	T.S.	G.
0.25	780		2.0	250	
0.3	795		2.1	425	
0.5	870		2.4	270	
0.5	480		4.2	345	
0.6	495		10.0	195	
1.0	330		12.0	208	
1.2	345		21.0	284	

Circles containing dots indicate less growth

the dominant ion since the best growth occurs at Ca/Mg ratios between 3:1 and 24:1. This might also indicate that quantities of Ca as such are more important than M/D and Ca/Mg ratios. Pearsall[5] reports that diatoms are present only in calcareous waters having an M/D ratio below 1.5. The *in vitro* data correspond well, and suggest that, for this species at least, Ca/Mg ratios higher than the one existing in calcareous waters (6:1) may be ecologically important if the nitrate, phosphate, and silica concentrations are not limiting. *Fragilaria* tolerates wide variations in total solid concentrations (from 200 to 900 p.p.m.). Lower total solid concentrations are probably as advantageous: *(a)* The species was isolated from natural waters of 50 p.p.m. total solids; and *(b)* in our experiment the lower total solid values were explored but combined with unfavorable M/D ratios. K does not seem to be limiting from 2 p.p.m. upward. This species prefers a preponderance of divalent ions and may have an unusually high need for Ca as indicated by the difficulty in substituting Mg for Ca even at the best M/D ratio.

(C) Peridinium balticum. This organism seems restricted to a narrow zone of salinities, the upper limit being 20 parts per thousand. The experimental design had large increments in salinities and ratios, and is not well-suited for a sensitive organism.

Our experiments appear to characterize *Peridinium* as a stenohaline organism with fresh-water tendencies. Yet we have observed that *P. balticum* can be transferred from 10 parts per thousand directly to 30 parts per thousand salinity without losing motility, and that motility in sea water is maintained for days. High salinities, while not obviously toxic, do not permit normal division.

(D) Exuviella cassubica. E. cassubica shows a remarkable ability to grow in a wide range of salinities (8 to 41 parts per thousand) and M/D ratios (3 to 62). It is clearly a flexible euryhaline organism with a predilection toward dilute brackish waters. Resistance to salinity is generally expected from brackish organisms because in nature this environment has rapid and wide changes of concentrations. Although the ability to grow at different salinities is an ecological asset, not all brackish species have this, *e. g., Peridinium balticum.* The resistance to a wide variation in M/D ratios is a valuable potentiality of the organism; it permits the formulation of media quite different from sea water and less precipitable, but it is probably of no ecological consequence. *E. cassubica* can grow well at widely different ratios of Ca/Mg.

(E) Svracosphaera carterae. S. carterae is very similar to *Exuviella cassubica* in its great tolerance towards salinities, wide variations in M/D and Ca/Mg ratios. It

distinctly prefers sea water salinities, however. This species had been found only in a pool on the Isle of Wight and in an oyster pond in Norway. M. Parke (personal communication) reports its presence in waters well out off Plymouth. The laboratory data parallel the ecological observations.

(F) Rhodomonas lens. Salinity and M/D ratios seem to be important both for good growth and in determining the ability to grow at varied Ca/Mg ratios. This becomes clear if one reads TABLE 9 vertically, *i. e.*, at similar salinities; the response then depends mainly on the M/D ratios. The range of favorable salinities and of M/D ratios is far more restricted than that displayed by *Exuviella* and *Syracosphaera* and shows that this organism is relatively inflexible; its most favorable conditions for growth center around sea-water ratios and concentrations. Optimal growth accompanied by the greatest indifference to changes in Mg/Ca ratios is displayed at 22 parts per thousand salinity and at an M/D ratio of 12 (double the sea-water ratio). This is a very favorable condition because it permits use of more dilute media and lowers the level of the more easily precipitating divalent elements. It should be noted that very good growth is obtained, as compared with the other species considered, at other salinities and M/D ratios, but only at specific Mg/Ca ratios.

Discussion and Conclusions

These experiments, which explored wide variations in inorganic nutrients, detected some nutritional specializations. On the whole, the *in vitro* results harmonize with the ecological observations.

The need of a low M/D ratio by *Fragilaria capucina* confirms Pearsall's[4] observations that diatoms prefer water of M/D ratios < 1.5.

Synura sp. exemplifies an organism sensitive to the interaction of concentration of total solids and M/D ratios. No ecological data are available for this particular species. Other *Synura* species, however, are known to prefer oligotrophic waters.

Peridinium balticum and *Exuviella cassubica*, though both isolated from a low-salin-

TABLE 9

BRACKISH AND MARINE ORGANISMS

	Peridinium			*Exuviella*			*Syracosphaera*			*Rhodomonas*		
M/D \ S.	8-12	20-24	38-42	8-12	20-24	38-42	8-12	20-24	38-42	10-15	20-24	38-42
118			○			◔			◑			○
62		◑			●			◕			◑	
48			○			◑			●			◔
24	◕	◔	○	●	◕	◕	◔	◕	◕		◕	◕
12	●	◔	○	◕	◕	◔	◕	◕	◑	○	●	◕
6	◕	○		◕	◑		◕	◑		◔	◕	
3	◑			◕			◑			◑		

M/D = monovalent/divalent ratio; S = salinities in ‰.

ity brackish pond, show a different pattern of growth as related to salt concentration ("salinity"). *E. cassubica* is euryhaline with neritic tendencies. Its growth responses to different salinities correspond closely to those found by Braarud[6] in cultures of *Exuviella baltica;* he remarked that the *in vitro* observations agreed well with the distribution in nature. *P. balticum* seems to be stenohaline, but preferring a low salinity; however, according to Biecheler[7] it is euryhaline. This discrepancy may be explained by our observation that it retains motility for many days at salinities from 5 to 35 parts per thousand but it multiplies only at low salinities.

Syracosphaera carterae, according to Braarud, is euryhaline with oceanic tendencies. Our data agree.

Rhodomonas lens is much less euryhaline and has oceanic tendencies.

These preliminary data already indicate the inherent wide physiological flexibility of some phytoflagellates and the latitude allowed in formulating culture media for marine flagellates. As mentioned, the experiments were designed to find the possible absolute effect of the Mg/Ca ratio at varying M/D ratios and total solid concentrations. These data were required because the Mg/Ca ratios are, aside from total solid concentration, the salient differences typifying sea water and fresh water. This complete reversal of ratios in the two types of water is shown in TABLE 1. It might be supposed, therefore, that marine organisms would prefer Ca/Mg ratios close to seawater (1:3) and fresh-water organisms the 6:1 ratio. While this may hold at salt concentrations and M/D ratios similar to those of their habitat, it was shown, for each of the organisms tested, that at a specific salt concentration and M/D ratio, Ca and Mg are widely interchangeable (when both are present) and that deviations from this particular TS and M/D ratio may still allow maximum growth but only at restricted Ca/Mg ratios. The few species studied and the sketchy experiments do not permit generalizations on the importance of total salt concentration and M/D ratios. Several species; *e.g., Synura, Rhodomonas,* and *Peridinium,* show interactions of total salt concentrations and M/D ratios; however, for *Fragilaria* the M/D ratio and the preponderance of Ca seem more important. After submission of this paper we found that Vollenweider[8] had studied the need for Ca and Mg in 3 diatoms. He concluded: a) that high Ca is needed; b) that there exists, within limits, an interchangeability between Ca and Mg; c) that a certain balance between the two ions may be needed; the addition of higher concentrations of Mg is necessary with high Ca.

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References

1. RODHE, W. 1949. The ionic composition of lake waters. Verhand. Internatl. Verein. theor. angew. Limnol. **10**: 377-386.
2. STORM, J. & S. H. HUTNER. 1953. Nutrition of *Peranema.* Ann. N.Y. Acad. Sci. **56**(5): 906.
3. PROVASOLI, L. & I. J. PINTNER. 1953. Ecological implications of *in vitro* nutritional requirements of algal flagellates. Ann. N.Y. Acad. Sci. **56**(5): 839-851.
4. HUTNER, S. H., I. PROVASOLI & J. FILFUS. 1953. Nutrition of some phagotrophic freshwater chrysomonads. Ann. N.Y. Acad. Sci. **56**(5): 852-862.
5. PEARSALL, W. H. 1922. A suggestion as to factors influencing the distribution of free-floating vegetation. J. Ecol. **9**: 241-253.
6. BRAARUD, T. 1951. Salinity as an ecological factor in marine phytoplankton. Physiologia Plantarium **4**: 28-34.
7. BIECHELER, B. 1952. Recherches sur les Peridiniens. Supp. Bull. biol. France Belg. **36**: 149.
8. VOLLENWEIDER, R. A. 1950. Oekologische Untersuchungen von planktischen Algen auf experimenteller Grundlage. Schweiz. Z. Hydrol. **12**: 1-75.

DATA ON THE METAL REQUIREMENTS OF *TETRAHYMENA PYRIFORMIS**

By R. P. HALL**

Earlier observations, involving the inhibition of growth by chelating agents added to a medium for *Tetrahymena pyriformis*, have suggested that Ca plays a significant role in the growth of this ciliate.[3] The basal medium used in these experiments contained two peptones, dextrose, and supplementary thiamine and K_2HPO_4, and was known to be contaminated with appreciable amounts of Ca, Fe, Mg, and Mn. The addition of EDTA (ethylenediaminetetraacetic acid) in concentrations calculated to form complexes with the Fe and Mn and most of the Ca contaminants, leaving the Mg undisturbed, resulted in more or less complete inhibition of growth. Essentially complete reversal of inhibition was produced by adding any one of certain metals to the EDTA-medium. The effective metals included Ca and also several others (Al, Co, Cu, Fe, Mn, Ni, Zn) which form more stable complexes than Ca does with EDTA and would thus tend to displace Ca from its EDTA-complex.[1, 2, 4, 7] Two metals which form less stable complexes than Ca were also tested for reversal of EDTA-inhibition. Of these, supplementary Sr failed to increase the density of population beyond that observed in the control medium with EDTA. Added Mg produced only a slight reversal, and the observed effects may not be attributable entirely to Mg, in view of the Ca content of the Mg-salt. It seemed obvious that supplementary Mg had not displaced from its EDTA-complex any essential metal lower in the stability series. Furthermore, the data indicated that displacement of complexed Mg, if any, by added Ca could not have been a significant factor in the reversal of inhibition produced by supplementary Ca. Such contaminants as Fe and Zn were present in the Ca-salt in concentrations far below the levels which have induced detectable growth-responses to these metals in EDTA-medium. Hence, the trace metals in the Ca-salt would seem to have no appreciable bearing on the observed results.

In a search for additional data, peptone medium was pretreated with various cation exchange resins in the hope of inducing metal deficiencies which could be relieved by specific supplements. In the first tests, with a resin of the carboxylic type, growth of *T. pyriformis* could be partially or completely inhibited, depending upon the extent of pretreatment. Among several metal supplements tested, Mg was the only one which restored growth to approximately normal levels.[3] These findings are in accord with previous reports that Mg is required by *T. pyriformis*.[5, 6]

Attempts were made to substitute certain other metals for Mg as supplements to the same type of pretreated medium. Some of these metals have been reported to be more or less effective substitutes for Mg in the activation of certain enzymes. The serial-transfer technique was followed in testing the various metals. In the first transfer out of a complete medium, growth approached a normal level with added Mg, was insignificant with Sr, and was rather poor with each of several other metals (Al, Ca, Co, Mn, Ni, Zn). With supplementary Mg, comparable populations were obtained through five additional transfers, the dilution factor exceeding 1×10^{10} in the sixth transfer. No growth occurred in the second transfer (dilution of original inoculum, 560 : 1) with any of the other metals. It thus appears that, no matter what roles these other metals may play in the activation of enzymes in extracellular preparations, none of them is an effective substitute for Mg in the growth of *T. pyriformis*.

*This paper, illustrated with lantern slides, was the third of three papers presented at a meeting of the Section on May 10, 1954.

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Successive pretreatments of peptone medium with a carboxylic and a sulfonic resin produced somewhat more extensive depletion. The addition of Mg (0.1 mg per cent) to such a medium (supplemented with Co, Fe, Mn, and Zn) restored growth only to about half the normal level after 10 days of incubation. Combinations of Mg and Ca (0.05-0.2 mg per cent) produced further increases in yield (20 to 50 per cent), indicating at least an accelerative effect of the added Ca. Without Mg, growth in the basal medium was poor; however, supplementary Ca, in the highest concentration tested, again produced significant stimulation. In either case, the magnitude of the effect was such that it could not be attributed to the small amount of Mg contaminating the Ca-salt.

These observations tend to support the conclusion, suggested by the results obtained with EDTA, that Ca is a metal ion of some physiological importance in the growth of *T. pyriformis*. Attempts are in progress to determine whether or not the apparent relation of Ca to growth of this ciliate is a specific one, as does seem to be the case for Mg.

References

1. ALROSE CHEMICAL COMPANY. 1952. Sequestrene. Providence, R. I.
2. BERSWORTH CHEMICAL COMPANY. 1953. The Versenes. Technical Bull. No. 2. Framingham, Mass.
3. HALL, R. P. 1954. Effects of certain metal ions on growth of *Tetrahymena pyriformis*. J. Protozool. 1: 74-79.
4. HUTNER, S. H., L. PROVASOLI, A. SCHATZ & C. P. HASKINS. 1950. Some approaches to the study of the role of metals in the metabolism of microorganisms. Proc. Am. Phil. Soc. 94: 152-170.
5. KIDDER, G. W., V. C. DEWEY & R. E. PARKS, JR. 1951. Studies on the inorganic requirements of *Tetrahymena*. Physiol. Zoöl. 24: 69-75.
6. SLATER, J. V. 1952. The magnesium requirement of *Tetrahymena*. Physiol. Zoöl. 25: 283-287.
7. WILLIAMS, R. P. J. 1953. Metal ions in biological systems. Biol. Revs. Cambridge Phil. Soc. 28: 381-415.

SECTION OF PSYCHOLOGY

RECENT EXPERIMENTS IN PERCEPTION*

By FRANKLIN P. KILPATRICK**

In the following remarks I am acting largely in the role of a reporter. The point of view regarding perception and perceptual learning and the research findings discussed in this paper did not, for the most part, originate with the author. They are a joint product of a number of us who have been fortunate enough to be able to cooperate in systematic perceptual research during the last few years. One group is located at Hanover, N. H., another at Princeton University, and another at the Naval Medical Research Institute, Bethesda, Md. It is hoped that what is said here does not distort too much the views and the research results of the other members of our group.

For the most part my remarks will be confined to the area of visual perception. Our investigations in the field of visual perception have been systematic in that a particular theory of perception has guided the work; the theory which has been called "transactional." We often have been asked the origin of the term transactional and why we use the word anyway. We have borrowed the term from Dewey and Bentley,[3] and we mean by it about the same thing that Dewey and Bentley do. They explain it in terms of the buyer-seller analogy, pointing out that it is impossible to define the functional nature of the buyer *as* buyer apart from his transaction with the seller, and that it is likewise impossible to define the seller *as* seller apart from the transactional nature of his relationship with the buyer. Similarly, we feel that the perceptual process can best be thought of as a transactional one; that is, that the perceptual process is a total one, involving all aspects of living. Such concepts as organism or environment are static abstractions from this total process and may be properly understood only if it is remembered that each of them involves, at least to some degree, all aspects of the process.

It is not my intention to spend any great amount of time elaborating theory as I want to move rather quickly to a description of some of our recent experimental work, much of it as yet unpublished. It may be helpful, however, in understanding the experiments if I simply point out some major assumptions of transactional theory.

As a result of earlier work, principally with the perceptual demonstrations designed by Adelbert Ames, Jr., it was proposed that perception might best be conceived of and treated as process. It was further suggested that perceiving is primarily a learned activity of the organism; that actions and their consequences as they are registered in relation to our motives or purposes are instrumental in the construction of what we see. It is our conviction that the perceptual organization of the moment cannot be an absolute revelation of what is, but is instead a sort of "best bet" based on past experience. This "best bet," based on the consequences of past dealings with our environment, is expressed in awareness as perceiving, and serves as a directive for further dealings with the environment. We are accordingly motivated and behave in terms of the world as we perceive it, and the world as we perceive it is in large part a product of our past motivations and behavior.

Implicit in this theory, as briefly outlined, is a rejection of the usual sort of interactional analysis. By the usual sort, I mean the interactional analysis that implies independent entities with an organism on one side and an objectively definable en-

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vironment on the other, with some sort of interaction occurring between the two. Our theoretical view does not subscribe to such a bifurcated universe.

Also in this theory is a rejection of the usual cause-effect analysis. We often slip into cause-effect analysis with its implications of independent entities and one-way relationships, but our ideal is what might be called "except-for" analysis. "Except-for" analysis implies simply that we are trying to abstract those aspects of the total process "except-for" which the process itself would not occur as it does; and also, to the extent that we are able, to specify the role that such abstracted variables play in the process.

A further aspect of our work about which people often ask ties in very closely to this latter point. People want to know why we make such extensive use of illusions in our work. Perhaps I can answer this question best and make clear its relationship to my previous point by offering an example. Suppose I set before you a water glass and you look at it and reach out and touch it. There is an almost perfect correspondence between your perception at one point in time, your action, and your perception at a subsequent point in time. But this tells us very little about the process of perceiving. Now, if I leave the water glass where it is and leave you where you are, but alter just one factor, and you now perceive and reach for the water glass in other than its true position, it seems fair to assume that the altered factor plays a definite and perhaps determinable role in your perceiving. It does not seem reasonable to say, however, that the altered factor "caused" you to see the water glass where you saw it either the first time or the second time; it is merely one aspect which made a difference in a total process; an aspect except for which your perceiving would not have been organized in the way that it was.

The preceding, then, is a brief summary of some of the major points of transactional perceptual theory. This theory has been subjected to a great deal of criticism, and it would be unrealistic to suppose that not any of the criticism is justified. Regardless of its other merits or demerits, however, the approach does seem to be stimulating some interesting research.

I should like to describe some of this research under three major headings. The first group of experiments is concerned with the effects of what might be called "stress," "anxiety," or "insecurity" in visual perception; the second with selective perceptual distortion under conditions of artificially induced distortion; and the third, with the problem of perceptual learning.

Stress Experiments

It should be pointed out at the beginning that stress is a very general, and probably inaccurate, name for a general class of phenomena with which we have been dealing. It is merely a descriptive term employed in lieu of more accurate specifications of the physiological and psychological factors involved.

The first experiment in this general line is one in which Hastings[4] used a paper-and-pencil personal-security inventory as a means of selecting contrasting groups of secure and insecure subjects, and obtained size-distance judgments from them on the "thereness-thatness" apparatus designed by Ames.[5] The differences between the settings given by the two groups were marked and highly reliable. It appears that even in such simple aspects of perceiving as of size and distance some sort of tension or general stress level which might be presumed to be different for the two groups of subjects must be taken into account. Further work of a somewhat different kind by Smith[8] tends to confirm this conclusion.

Perhaps even more confirmation is offered by the work of Slack and Calloway, as yet unpublished, on the effects in perception of

"stress" artificially induced by cold-pressor or amyl-nitrite. They found that size-distance judgments in the laboratory and outside, in a normal environment, were reliably affected by putting one's foot in a bucket of ice water or by inhaling amyl-nitrite. Slack also conducted preliminary studies using the technique of one-dimensional tracking as a means of continuously recording alterations in perceptual-motor behavior. In testing the effects of cold-pressor and amyl-nitrite, he found that both conditions result in a change in what is called the "range-effect," a sort of regression toward the mean.

Another bit of research in this line involved the use of aniseikonic glasses in the "leaf room." For almost every observer there is an appreciable time lag between putting on these distortion-producing glasses and the appearance of any distortion of the room, and even more time elapses while the apparent shape of the room gradually alters until it finally reaches a fairly stable maximum.[5] A device for measuring the speed and amount of this perceptual alteration has been designed by Ittelson. One of the experiments (not yet published) in which it has been used also involves the use of cold-pressor and amyl-nitrite. Both of these seem to result in an appreciable reduction in both the speed and amount of perceptual alteration. This result and the tracking results might well be interpreted in the same fashion; that is, as an increasing reliance on some sort of previously constructed "constancy," and less reliance on immediately available cues which call for change.

Selective Perceptual Distortion

The studies to be summarized under this heading cannot be clearly differentiated from those described in the preceding section. In many instances, the same or similar apparatus was employed, and there are signs that the two groups of experiments may be subsumed under the same explanatory framework.

Wittreich[9] has conducted a number of experiments employing monocular distorted rooms[5] as basic apparatus. One of the distorted rooms he used is about the size of a small dining room, and appears quite normal when the interior is viewed with one eye through a hole in the door. It is not the normal cubical room it appears to be, however. Actually, the floor slants down from right to left, the ceiling slants up from right to left and the back wall recedes in the same direction; all at angles of about 20 degrees. When another person is seen in the room the usual result is marked distortion of his appearance. In the left rear corner he looks like a midget; as he walks toward the right rear corner he appears to grow larger and larger until, finally, he looks like a giant. This change in appearance is the usual result. However, Wittreich's work shows that these alterations in appearance are not entirely predictable on the basis of the geometry of the room; the personal relationship between the between the person viewing and the person being viewed frequently plays an important part. It is quite common, for example, among couples married under one year to find that a wife or husband viewing his or her marital partner moving about in the room will perceive very little change in size; the marital partner continues to look normal or very nearly normal in size anywhere in the room. But when a stranger of either the same or opposite sex replaces the marital partner in the room, the same observer sees the change in size in full amount. This tendency toward "person constancy" is not simply a function of familiarity, since it is not ordinarily found among couples who have been married longer than one or two years.

Comparable results emerged from the use of aniseikonic size lenses with children. These lenses, referred to previously, alter the relative sizes of the retinal images in the two eyes, usually resulting in marked distortion in the perception of whatever is being viewed. In one experiment with children such glasses were put on the child and

he was asked to look at both his parents and to describe how they looked. In a number of instances one parent was reported as distorting markedly in appearance while the other remained either normal or almost normal. Similar results were obtained when the children observed their parents in the monocular distorted room.

A study in the same line, soon to be published, was recently completed by Gilder and Wittreich. They had observers look at normal people and simulated amputees while wearing aniseikonic size lenses. The results were unequivocal and in line with the investigators' predictions. The observers consistently reported seeing more distortion of the normals than of the simulated amputees.

In looking over this group of experiments one is tempted to generalize. If one merely postulates that among newly married couples distortion in the appearance of the marital partner is somehow threatening and tension-arousing in many instances; that for children the same thing is often true with respect to one parent more than another; and further, in the case of the amputee study, that perceived bodily mutilation, even simulated, is somehow tension-arousing; then it would appear that the studies in this section could be subsumed under the same sort of explanation as was postulated for those in the preceding section. The generalization would be that whenever tension or stress is aroused, the individual tends in his perceptual organization to resist the change called for by new impingements from the environment, and to hold on to a stable perceptual construct, or constancy. Probably this resistance occurs because the constancy, in spite of the fact that it may not be appropriate or reliable in this immediate situation, has proved reliable in the past.

Perceptual Learning

It has long been agreed that perceptual learning does occur, and an enormous amount of space in journals and books has been devoted to the question of how much of our perceiving can be accounted for by learning. Surprisingly little attention, however, has been devoted to what appears to me to be the more fundamental problem of how perceptual learning occurs. It is to this question that the experiments reported in this section were devoted.

The experiments utilized small monocular distorted rooms as perceptual learning and testing devices. When the interior of such a room is viewed with one eye from the proper position it is seen as being perfectly normal in shape, just as in the case of the large distorted room previously described. No amount of advance knowledge concerning the actual shape of the room and no amount of time spent in just looking at the static configuration is effective in altering the way in which it is seen. The observer can learn through other means, however, to see more and more of the true shape of the room. Here we have a device admirable for studying the process of perceptual learning. This learned alteration is gradual, progressive, and measurable, making it possible to analyze the effects of systematically altering such variables as amount of practice, kind of practice, motivation, amount and kind of conflicting cues, *etc.* Through the use of these distorted rooms we feel that we have learned something about some of the processes involved in perceptual learning, and something about the role of action in perceptual learning.

To avoid lengthy apparatus and procedural descriptions soon to appear elsewhere in print,[7] only the major conclusions of the studies will be set down here.

(1) It appears necessary to distinguish between what I have called for want of better terms "cognitive perceiving" as opposed to "modal perceiving." When an observer practices at one of the distorted rooms, the typical result is that he gets an understanding of the true shape of the room

considerably in advance of any alteration in the way he *sees* it. That is, after the first practice session the room may not have changed in visual appearance for him at all; nevertheless, if asked to describe how he thinks the room actually is, or asked to draw what he believes to be the shape of the room, the observer, typically, is able to come quite close to the true structure. Certainly he *perceives* at least to some extent the true shape of the room, but we may say that his alteration in perception is being reflected cognitively rather than being reflected in the visual modality. Only after further practice is there a modally reflected alteration in perception, experienced by the observer as a seeing of the room in a different way.

(2) Cognitive perceiving has an initial inhibitory effect on modal perceiving in the distorted-room perceptual-learning situation.*

(3) Within modal-perceptual learning, two further processes have been distinguished experimentally. The first process I have called "reorganizational" learning. It is a process in which an unconscious reweighting of visual cues occurs. Unavoidably present in every distorted room are cues that we are able to perceive in ways not in harmony with the dominant percept; thus they have the potential of functioning as "give-away" cues. These cues, which give away to some degree the distortions present in the room but are not at first utilized, are given greater and greater weight as the incompatabilities between the original percept and the consequences of the practice continue to be registered, with the result that changes in the apparent shape of the room occur. The cues referred to are those which are present because of minor defects, perhaps almost impossible to correct, in construction, lighting placement of the observer's eye, and so forth; also, of course, these cues may be deliberately introduced.

The second process I have called "formative learning." This process, it seems to me, is far more crucial than the first in terms of perceptual theory. It consists of an actual learned alteration in the way in which a given stimulus pattern is perceived, yielding a new perception which is not dependent on the utilization of "give-away" cues. It is a learning process in which the perception of the basic configuration related to that particular distorted room, a cubical reference room, or equivalent distorted rooms of any shape, is modified. Reorganizational learning shakes up and rearranges the marbles in the bag; formative learning puts new marbles in the bag; and, if we are correct in our view, explains how most if not all of the marbles got in the bag in the first place.

(4) The notion previously proposed in transactional theory,[1, 2, 6] that gross overt physical action is necessary on the part of the observer for modal perceptual learning to occur, is clearly wrong. A more adequate formulation, probably centering on the sequential relationships of perceptual processes, is required.

Conclusion

I hope enough has been presented here to give the flavor of what we are trying to do. It is tempting to generalize the results of this work far beyond the point of safety, and I feel I must insert the caution that we do not yet have enough information to make it possible to say with assurance that our results are characteristic of the perceptual process in modalities other than visual, and in the more complex processes of daily living. It is our faith, of course, that at least some of them will prove to have such generality; but only through continued research by the many people in the field shall we be able to make generalizations without

*This experiment was conducted at Princeton University by James Bagby as part of a doctoral thesis still in preparation for Teachers College, Columbia University.

inserting many cautions concerning the uncertain state of our knowledge.

Perhaps you can consider transactional theory in that light. It is merely our best guess in the light of available experimental evidence; a "best guess" which serves as a guide and a framework for experimental research.

References

1. AMES, A., JR. 1951. Visual perception and the rotating trapezoidal window. Psychol. Monogr. 65: (7) (Whole No. 324).
2. CANTRIL, H. 1950. The "Why" of Man's Experience. MacMillan. New York.
3. DEWEY, J. & A. J. BENTLEY. 1949. Knowing and the Known. Beacon. Boston.
4. HASTINGS, P. K. 1952. An investigation into the relationship between visual perception and level of personal security. In Human Behavior from the Transactional Point of View. F. P. Kilpatrick Ed. Institute for Associated Research. Hanover, N. H.
5. ITTELSON, W. H. 1952. The Ames Demonstrations in Perception. Princeton Univ., Press Princeton, N. J.
6. KILPATRICK, F. P. 1952. Statement of theory. In Human Behavior from the Transactional Point of View. F. P. Kilpatrick Ed. Institute for Associated Research. Hanover, N. H.
7. KILPATRICK, F. P. 1954. Two processes in perceptual learning. J. Exptl. Psychol. In press.
8. SMITH, G. H. 1952. Size-distance judgments of human faces (projected images). In Human Behavior from the Transactional Point of View. F. P. Kilpatrick Ed. Institute for Associated Research. Hanover, N. H.
9. WITTREICH, W. J. 1952. The Honi phenomenon: a case of selective perceptual distortion. J. Abnorm. and Soc. Psychol. 47: 705-712.

*SECTION OF ANTHROPOLOGY**

MANUS RESTUDIED: AN INTERIM REPORT**

By MARGARET MEAD***

During the last seven years an interdisciplinary group[1] of anthropologists, psychologists, political scientists, and historians have been developing an approach to social change, particularly to change which involves profound ideological shifts such as occurred in the Soviet Revolution and in the contemporary adoption of communism in China, in which an attempt has been made to relate the prechange cultural character to the direction of change. Bolshevism, for example, was construed as a special counterpoint to the old Russian ambivalence towards control and sharp mood swing, in which the control was tightened and internalization of external sanctions made the ideal, and the mood swings combatted and interdicted.[2] In China, the ambivalence of the Chinese towards the excessive demands of the extended family was seen as background for the wider sense of social responsibility that the communists offered, with its accompanying repudiation of parental control of marriage, private life, and economic loyalty.[3]

In all of these analyses, however, we have been hampered by lack of material on the actual individuals who participated in these changes. It has been difficult to assess—especially where populations of millions in modern nation states were concerned—to what extent the new ideologies were originated by deviant personalities, or from classes having a different version of the culture; and to what extent the postulated regularities, with consistent discontinuities and discrepancies on which the new ideology could be based, were characteristic of the whole culture.

There was also a growing literature on the expression of cultural change in the personality organization of individuals who had been studied, as individuals, and then used as indicators for the growth of such modern urban phenomena as "anomie," "marginal men," "political apathy," and other precursors of totalitarian regimes.[4]

Manus, largest of the Admiralty Islands, in the southwest Pacific, administratively a part of the Territory of New Guinea, was chosen for study because it has been the scene of a striking, recent cultural change and because published records were available on the present adults as children, on the former culture in which those adults had been reared, and on the interaction system of a village community, Pere, which had been studied as a whole. This community, moreover, still existed, so that the predicted inter-relationships between individuals could be compared with the present relationships after the change had occurred.[5]

Methods of Research and Areas of Expected Publication

The 1953-1954 field team consisted of Mr. and Mrs. Theodore Schwartz of the University of Pennsylvania Graduate School and myself. I spent the period of June through December 1953 in the field; Mr. and Mrs. Schwartz planned to remain in the field until the end of June 1954. As all their later notes and observations are not yet available, this is necessarily a tentative and partial report. The undertaking, a

*The Section of Mathematics and Engineering held a meeting on May 21, 1954 at which a paper entitled "Applications of Operations Analysis to Industrial Experimentation" was read by E. R. Bowerman. No abstract of this paper has been received.

The Section of Oceanography and Meteorology held a meeting on May 25, 1954 at which a paper entitled "The Jet Stream in the North Atlantic" was read by E. B. Buxton and C. L. Chandler. No abstract of this paper has been received.

The Division of Mycology held a meeting on May 28, 1954 at which a paper entitled "A Microbiologist Looks Over the Cheese Market" was read by Charles Thom. No abstract of this paper has been received.

**This paper, illustrated with lantern slides and sound motion pictures, was presented at a meeting of the Section on May 24, 1954.

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regular expedition of The American Museum of Natural History, was supported in part by special grants made by the Rockefeller Foundation and the F. G. Voss Fund for Anthropological and Archaeological Research. The expedition was designed as a methodological study of the problems and possibilities involved in the restudy of a primitive community, under extreme changed conditions, with a focus on the dynamics of change within one generation.

The whole question of anthropological restudies[6] has been primarily oriented toward meeting the objection of students of our own society that the work of individual anthropologists was not subject to the traditional rechecking customary in the physical sciences. The present investigation was not designed to deal with this problem, although it throws some incidental light upon it. I am still of the opinion that the best test of the validity of ethnological material and the reliability of the methods of observation used is a split-halves analysis of all of the data collected by the original investigator or investigative team. But this particular research was designed to use to the full the special experience of the senior ethnologist's former detailed work on the same community and the present adult group as children to obtain useful new hypotheses through the utilization of a unique situation. It was also designed to contribute to a critical evaluation of the methodological and conceptual innovations of the last 25 years during which the culture and personality approach has developed.

The original work on Manus, the second field trip for both Doctor Fortune and myself, was a first attempt to do systematic work on young children in a primitive culture, and was among the first studies in which the ethnologists learned to speak the native language. It was a first attempt to handle a single community and its entire population and event sequence over a definite period of time, as a microcosmic laboratory of the situation.[7] Moreover, it was a first attempt to use projective tests, to make a systematic use of children's drawings, and to project the pattern of interpersonal relationships in the children's group into the future. Photographic methods were limited to still photographs taken for purposes of illustration. There is a large body of verbatim material, but this was collected either because it was regarded as proper to record texts, or because the work was being done and recorded in the native language, or to establish psychological nuances. The methodological importance for personality study of verbatim recording of large blocks of verbatim material had not been recognized.[8] There were no motion pictures, no tape recordings, no projective tests except those that I devised myself on the spot, no systematic approach to nonverbal behavior.[9] Most of the significant conceptions of the culture and personality approach were still to be developed: the concept of cultural character,[10] the role of the individual in reinterpreting his culture,[11] the importance of the patterning of modes and zones,[12] the circular character of parent-child relationships,[13] end linkage[14] and schizmogenesis,[15] ego psychology and the cultural variations in defense mechanisms,[16] applications of learning theory to cultural material,[17] applications of studies of growth, constitution, and temperament,[18] the cybernetic approach[19] and its complement the "living model,"[20] the relationship between character structure and political form,[21] ego structure in culture,[22] the applications of ethology,[23] the "proto system" of Margaret Lowenfeld,[24] and the "cosmic sense" of Edith Cobb.[25]

We worked with a general knowledge of psychoanalytic theory, particularly the study of dreams, before the emphasis on the ego and character analysis; a knowledge of Piaget's early work; a formal academic knowledge of child psychology; and a little

knowledge of child development. Psychosomatic medicine had not been born; projective tests had not been named; the possibilities of machine devices in the recording and analysis of human behavior all lay in the future.[26] We worked with an orientation in anthropology and social research derived from Boas, Ogburn, Benedict, Sapir, and Radcliffe Brown.

An analysis of the materials will be done in terms of (1) comparisons: of Pere village, its structure and function, 1928-1929, 1953-1954; the projective and observed behavior of adults with their childhood records and of their actual structural role with their projected structural role; the drawings and other projective performances of the children of today's Pere with the children of 1928, and with the children of Mbunai, which is a mixed village of Manus and Usiai; a four-months event sequence in Pere, 1928, with a four-months event sequence in 1953, from records made in 1928 and from individual memories of these events in 1953; the patterns of perception, thought, and creativity as between Pere 1928 and Pere 1953; and the economic and social structure with special reference to kinship and methods of mobilizing productive effort, in 1928 and 1953; and (2) a detailed study of the present modern movement, and a historical reconstruction of its history since 1946; the functioning of the new system in Pere and Mbunai and briefer studies of its history and the personality of the leaders in other villages; a study of change in the Manus language and a comparison with contemporary Usiai dialects and the lingua franca, Neo Melanesian (formerly called "pidgin English"); a study of the relationship between actual constitution, the character of which would be attributed to the constitutional type as revealed by ordinary photographs and the cultural character and individual role of somatype photographs of identified individuals in Pere; and (3) a consideration of the significance of all the material for the processes of change taking place all over the world at the present time, especially in relation to rhythms of change, the extent to which whole communities and all generations change together, and the extent to which the change is felt to be imposed or spontaneous.

The inclusion of a husband-and-wife team of junior anthropologists in the 1953-1954 expedition ensured a bisexual approach to the material and a large enough team to handle the use of photographic and tape recording techniques in the field. It also made it possible to form some estimate of what results other "restudy" methods of Manus would have yielded, based on the use of published materials by a new field worker and, because Mr. Schwartz had attempted some reconstruction of the previous culture of an Usiai group of the Great Admiralty, it was also possible to estimate how much of the earlier materials could have been recovered in a contemporary study, with no backlog of previous work. Mr. and Mrs. Schwartz worked in another village, so we have data on the peculiarities of response of two communities to the same contemporary situations of climate, season, governmental action, cataclysm (volcanic threat), *etc.* Collectively our equipment included, in addition to the conceptual apparatus listed above, a knowledge of projective testing, sampling theory, structural linguistics, and modern art. We used 35-millimeter cameras equipped with rapid winders and long lenses, 16-millimeter cinema cameras having a power motor attachment to correct for photographer's choice of pauses, electronic flash equipment, and generator-driven floodlights and tape recorders. Our test battery included the Rorschach, Thematic Apperception Test, Stewart Ring Puzzle, Bender Gestalt, Mosaics, Revised Minnesota Paper Form Board, and Caligor's Eight Card Redrawing Test.

Results and Conclusions

In 1928-1929 the Manus were a primitive people lacking writing of any sort; they had just given up, under peaceful government coercion, warfare and the capture of foreign prostitutes. There was a small number of young men who had worked as indentured laborers, and a few men were away at work. The Manus spoke the developing *lingua franca* of the territory, then called pidgin English, and were learning to use the government courts and to handle money. They were preparing to adopt Christianity. Their own complex economic system, based on frequent markets, elaborate intertribal trade and intratribal affinal exchange, and enforced by the ghosts of the recently dead, was fully functioning. The period between 1930 and the Japanese occupation was one of slow change, missionization, and acquisition of literacy by the young men. In 1946 a movement of revolutionary proportions swept the Manus, led by Paliau of Balowan, a member of a small Matankor group. This movement included both careful planning for a new political social economy and outbreaks of a nativistic "cargo cult." The entire Manus tribe, together with sections of Usiai and Matankor groups, were combined into one political movement. The lagoon-dwelling Manus moved ashore and built new style villages, the old culture was systematically dissected, scrutinized, and in large part rejected, and a new culture designed to be of western type was built up. This development involved a break with the Mission and frequent nonviolent conflicts with governmental authorities which have been reduced by absorbing the group into a postwar administrative plan for local councils.

An analysis of the drastic changes under which the Manus have designed for themselves a new culture, modeled on modern western lines, makes it possible to: (1) trace the sources of their ideas; (2) identify the conditions which made the change possible; (3) identify the role of leadership; (4) identify the particular precursor cultural forms and their embodiment in cultural character which facilitated the change; and (5) identify present strengths and vulnerabilities in the system.

(1) The ideology derives from contact with Australian courts and district services; from experience of organized work on plantations and government stations; from Christian preaching about the brotherhood of man and the particular application of this ideology to racial equality; from an interweaving sense of an emerging ethnic identity and its reciprocal, an appreciation of the political structure of the world; and from experience with the various armies during the war, which included an enormous appreciation of certain American traits. These traits included treatment of each individual on his merits, high valuation on human life expressed in medical care and carelessness about material things, a type of human relations which were not based on the continuous invocation of either status or anger, experiences of western type marriage, appreciation of the usefulness of a single monetary standard for all transactions, an appreciation of wage labor, of the right of individuals to contract for their work, to withhold help from kin, and to choose their own sex partners, and an appreciation of the skills associated with keeping records, rapid precise communication, and all types of measurement—writing, clocks, calendars—and of labor saving machinery.

(2) The introduction of change was facilitated by the long period of disorganization during the war, when the principal leader and several minor leaders were behind the Japanese lines and others were behind the Allied lines, while the bulk of the male population, including adolescents and middle aged men had the varied experience of

contact with the enormous American troop concentration. During the war there was a period when there were no resident clergy. The high wartime technological level increased dissatisfaction with the cheap trade goods which were current in the territory; and experience in methods of handling European-white relationships other than the Australian methods, which were partly inherited from the conventions of German times, made them restive. Literacy had reached a high enough level so that it was possible for them to begin to write down local laws, keep letters and speeches made by leaders, minutes of meetings, vital statistics, *etc.*, which increased their sense of their own ethnic identity.

(3) The leadership group, including Paliau, came from a fairly narrow age group, men between 14 and 20 in 1930 who had a long work experience which included the war years and who had not been completely caught back into the system of economic enterprise and exploitation within their own villages. The ethnically deviant, men who were of mixed (Admiralty) island descent or who had changed their village allegiance, played an important role, as they had in the past, exploiting wider kin ties and exhibiting greater detachment about local customs. Meanwhile the "cargo cult" mysticism which broke out sporadically in connection with the responsible effort to organize a local society on cross-tribal lines, utilized the less stable and the illiterate, and served both to crystalize social support for the internal changes and to justify European hostility against a movement which could be stigmatized as "insane" and "destructive," as well as truculent and demanding.

(4) The cultural system in 1928 showed certain instabilities. Children were reared with a high sense of responsibility for control of their own bodies, shame about sex and excretion, and respect for property. This early childhood training was invoked in adolescence, when young people found themselves caught in arranged marriages for which entrepreneurial leaders had paid. The amount of coercion in the system, in which the ghosts of the household demanded sexual purity (as far as Manus women were concerned) and economic responsibility, and punished infractions with illness and misfortune for self and kin, stood out sharply against the background of a long, willful, autonomous childhood, in which children did no work, owned no property, and lived in a companionable world closed against the quarrelsome exploitive standards of the adults. Adults supported their claims against each other by enormous displays of rage; angry scenes were a constant feature of social life, but anger was not valued, rather it was dreaded as possibly overwhelming the angry person and destroying the social structure. The economic system had hypertrophied to such an extent that transactions took place in millions and without record-keeping devices; it was clumsy and controversial. There was a flexible open-minded attitude towards new objects of material culture and new institutions; there was no cosmology, history, or coherent sense of the future within which change would have been difficult. In contrast, however, to the flexibility of the system—the capacity to form new types of power constellations—there was also a tendency to formalize any new development very rapidly.

(5) The principal vulnerability of the present system, with its newly established legal relationships to the local councils and cooperative systems of the Trusteeship Administration, lies first in its dependence upon the world situation at every level: defense, regional pacts, Australian policy in regard to New Guinea, United Nations policy, world prices for copra and wool, the policies of the internationally organized missions toward the present "heresies," *etc.* This enormous dependence upon outside conditions conflicts sharply with the

values of the new movement, values placed upon local self-determination, access to the technology of the wider world, freedom of movement, and an ability to develop their own system along their self-chosen lines. This conflict may be identified in ambivalence toward the administration, in continuing outbreaks of mysticism which might crystalize, if successful, into an other-world cult antagonistic to progress or the utilization of avenues of social advancement provided by government, and in the prevalence of gambling, instability of sex behavior, and some breakdowns in the former high standard of integrity and responsibility.

The strengths of the system lie in the way in which the whole group moved together, so that inter-relationships between generations and between peers were not seriously disturbed, in the extent to which the present leaders can actively compare the advantages of the new system with the disadvantages of the old, in the increased sense of ethnic identity and collective purpose, and the conviction of the Manus of their ability to tackle and solve any problem.

References

1. MEAD, M. 1953. National character. In Anthropology Today : 642-667. A. L. Krober, Ed. Univ. of Chicago. Chicago, Ill.; M. MEAD & R. METRAUX. 1953. The Study of Culture at a Distance. Univ. of Chicago. Chicago, Ill. (Gives details of these activities.)
2. MEAD, M. 1951. Soviet Attitudes toward Authority, McGraw-Hill. New York. (For discussion and bibliography.)
3. BUNZEL, R. & J. WEAKLAND. An Anthropological Approach to Chinese Communism. Columbia University Research in Contemporary Culture (Mimeo.); J. WEAKLAND. 1953. Chinese family images in international affairs. In M. MEAD & R. METRAUX. The Study of Culture at a Distance : 421-425. Univ. of Chicago. Chicago, Ill.
4. DE GRAZIA, S. 1948. Political Community, A Study of Anomie. Univ. of Chicago. Chicago, Ill.; G. W. ALLPORT, J. S. BRUNER & E. M. JANDORF. 1948. Personality under social catastrophe: ninety life histories of the Nazi revolution. In Personality in Nature, Culture and Society. C. Kluckhohn & H. Murray, Eds. Knopf. New York; N. LEITES. 1947. Trends in affectlessness. Am. Imago. (I)5(2): 89-112. E. KRIS & N. LEITES. 1947. Trends in twentieth century propaganda. In Psychoanalysis and the Social Sciences. Vol. 1. International Univ. Press. New York; E. STONEQUIST. 1937. The Marginal Man; A Study in Personality and Cultural Conflict. Scribner's. New York and Chicago, Ill.; M. MEAD. 1947. The implications of culture change for personality development. Am. J. Orthopsychiat. 17(4): 633-646; M. MEAD. 1949. Character formation and diachronic theory. In Social Structure. Studies presented to A. R. Radcliffe Brown : 18-34. Meyer Fortes, Ed. Oxford Univ. Press. London, England.
5. See list of publications on 1928-1929 Expedition appended to these references.
6. LEWIS, O. 1951. Life in a Mexican Village. Univ. of Chicago. Chicago, Ill.; O. LEWIS. 1953. Controls and experiments in field work. In Anthropology Today. A. L. Krober, Ed. Univ. of Chicago. Chicago, Ill.
7. MEAD, M. 1928. Coming of Age in Samoa. Morrow. New York. (Work on Samoa.); R. F. FORTUNE. 1932. Sorcerers of Dobu. Routledge. London, England. (Work on Dobu.) (In these two works every individual discussed was placed in the social structure and every event placed in time, but there was no systematic attempt to cover all individuals or all major events over a definite period.)
8. MEAD, M. 1949. The Mountain Arapesh. V. The Record of Unabelin with Rorschach Analyses. Anthropological Papers. American Museum of Natural History. 41(3): 289-390.
9. EFRON, D. 1941. Gesture and Environment. Kings Crown Press. New York. (For such approaches.); G. BATESON & M. MEAD. 1942. Balinese Character: A Photographic Analysis. Special Publications N.Y. Acad. Sci.; M. MEAD & F. C. MACGREGOR. 1951. Growth and Culture, A Photographic Study of Balinese Childhood. Putnam's. New York; R. BIRDWHISTELL. 1954. Introduction to Kinesics. Univ. of Louisville. Louisville, Ky.
10. DOLLARD, J. 1935. Criteria for the Life History. Yale Univ. Press. New Haven, Conn.
11. FRANK, L. K. 1939. Cultural Coercions and Individual Distortion. Psychiatry. 2(3): 2-27.
12. ERIKSON, E. H. 1950. Childhood and Society. Norton. New York.
13. MEAD, M. 1949. Psychologic weaning: childhood and adolescence. In Psychosexual Development in Health and Disease : 124-135. P. Hoch & J. Zubin, Eds. Grune & Stratton. New York.
14. MEAD, M. & R. METRAUX. 1953. The Study of Culture at a Distance. Part 9 : 365-390.

Univ. of Chicago. Chicago, Ill.

15. BATESON, G. 1949. The value system of a steady state. In Social Structure. Studies presented to A. R. Radcliffe Brown. Meyer Fortes, Ed. Oxford Univ. Press. London, England.

16. WOLFENSTEIN, M. & N. LEITES. 1950. The Movies, A Psychological Study. The Free Press. Glencoe, Ill.

17. DOLLARD, J. & N. E. MILLER. 1950. Personality and Psychotherapy; An Analysis in Terms of Learning, Thinking and Culture. McGraw-Hill. New York; G. BATESON. 1942. Social planning and the concept of deutero learning. In Science, Philosophy and Religion. Second Symposium. L. Bryson & L. Finkelstein, Eds. Conference on Science, Philosophy and Religion in Their Relation to the Democratic Way of Life, Inc. New York; G. GORER. 1943. Themes in Japanese culture. Trans. N.Y. Acad. Sci. 5(5): 106-124.

18. FRANK, L. K. 1935. Structure, function and growth. J. Philosophy Science. 2(2): 210-235; M. MEAD. 1947. On the implications for anthropology of the Gesell-Ilg approach to maturation. Am. Anthropologist. 49(1): 69-77; M. MEAD & F. C. MACGREGOR. 1951. Growth and Culture, A Photographic Study of Balinese Childhood. Putnam's. New York.

19. FRANK, L. K. *et al.* 1948. Teleological Mechanisms. Ann. N.Y. Acad. Sci. 50: 187-278; J. RUESCH & G. BATESON. 1951. Communication: The Social Matrix of Psychiatry. Norton. New York.

20. LAMB, R. K. 1952. The entrepreneur and the community. In Men in Business. : 91-119. W. Miller, Ed. Harvard Univ. Press. Cambridge, Mass.

21. FROMM, R. 1941. Escape from Freedom. Farrar & Rhinehart. New York.

22. ERIKSON, E. H. 1950. Growth and crisis of the healthy personality. Second Supplement to the Transactions of the Fourth Conference on Infancy and Childhood : 91-146. M. Senn, Ed. Josiah Macy, Jr. Foundation.

23. MEAD, M. 1954. Some theoretic considerations on the problem of mother-child separation. Am. J. Orthopsychiat. In press.

24. LOWENFELD, M. 1954. The Lowenfeld mosaic test. Newman Neams. London.

25. COBB, E. 1955. Cosmic sense in childhood recollections. In Childhood in Contemporary Cultures. M. Mead and M. Wolfenstein, Eds. Univ. of Chicago. Chicago, Ill. In press.

26. TANNER, J. & B. INHELDER. 1954. Study Group on Psychobiological Development of the Child. Proceedings of Second Meeting of World Health Organization, London. In press; R. SPITZ. 1946. The smiling response. Gen. Psychological Monograph. 34: 47-125, and film in N.Y. Univ. Film Library.

Publications on the 1928-29 Expedition Materials to Date

MEAD, M. 1937. The Manus of the Admiralty Islands. In, Cooperation and Competition among Primitive Peoples. Chap. 8 : 210-239. M. Mead, Ed. McGraw-Hill. New York.

MEAD, M. 1930. Growing Up in New Guinea. Morrow. New York. Penguin and Routledge. London.

MEAD, M. 1934. Kinship in the Admiralty Islands. Anthropological Papers. American Museum of Natural History. 34(2).

FORTUNE, R. F. 1935. Manus Religion. The American Philosophical Society. Philadelphia, Pa.

FORTUNE, R. F. 1931. Manus religion. Oceania. 2(1): 74-108.

MEAD, M. 1932. An investigation of the thought of primitive children with special reference to animism. J. Roy. Anthropological Inst. 62: 173-190.

MEAD, M. 1931. Two South Sea educational experiments and their American implications. Univ. Penn. Bull. 31(36): 493-497.

SPITZ, R. A. 1935. Fruehkindliches Erleben und der Erwachsenenkulture bei dem Primitiven, Bemerkungen zu Margaret Mead, Growing Up in New Guinea. Imago. 21: 367-387.

MEAD, M. 1930. Melanesian middlemen. Natural History. 30(2): 115-130.

MEAD, M. 1931. Living with the natives of Melanesia. Natural History. 31(9): 62-74.

MEAD, M. 1949. Male and Female. Morrow. New York.

CONFERENCES HELD

SECTION OF BIOLOGY

"LEUKOCYTIC FUNCTIONS"

MAY 27, 28, AND 29, 1954

The Section of Biology held a conference on "Leukocytic Functions." Doctor Albert S. Gordon, Graduate School of Arts and Science, New York University, New York, New York; Doctor John W. Rebuck, Henry Ford Hospital, Detroit, Michigan; and Doctor Robert S. Speirs, Roscoe B. Jackson Memorial Laboratory, Bar Harbor, Maine, were the Conference Co-Chairmen in charge of the meeting.

The program consisted of the following papers:

Thursday, May 27

INTRODUCTION TO THE LEUKOCYTES

Morning Session. Chairman: Paul Klemperer

"The Lymphocyte and Plasma Cell," R. Dorothy Sundberg, University of Minnesota, Minneapolis, Minn.

"The Neutrophilic Leukocyte," Joseph Sieracki, Henry Ford Hospital, Detroit, Mich.

"The Eosinophilic and Basophilic Leukocytes," Robert S. Speirs, Roscoe B. Jackson Memorial Laboratory, Bar Harbor, Me.

"The Monocyte," Edna H. Tompkins, New England Deaconess Hospital, Boston, Mass.

TECHNIQUES IN THE STUDY OF LEUKOCYTIC FUNCTIONS

Afternoon Session. Chairman: William Bloom

"Cinephotomicrography of Leukocytes," Joseph Victor, U.S. Army Chemical Corps, Camp Detrick, Md.

"A Method for Studying Leukocytic Functions *in Vivo* in Man," John W. Rebuck, Henry Ford Hospital, Detroit, Mich.

"Tissue Culture in the Study of Leukocytic Functions," Edwin E. Osgood, University of Oregon Medical School, Portland, Ore.

"Radiation and Protective Leukocytic Functions," Eugene P. Cronkite, Naval Medical Research Institute, Bethesda, Md.

Friday, May 28

FACTORS INFLUENCING NUMBERS, DISTRIBUTION, AND FATE OF LEUKOCYTES

Morning Session. Chairman: James L. Tullis

"Diurnal Variations," M. B. Visscher and Franz Halberg, University of Minnesota, Minneapolis, Minn.

"Sequestration of Leukocytes," Howard R. Bierman, University of California Medical Center, San Francisco, Calif.

"Studies on Leukocytic Secretory Activity," Kenneth M. Richter, School of Medicine, University of Oklahoma, Oklahoma City, Okla.

"Depressive Influence on Leukocytic Numbers," F. J. Heck, Mayo Clinic, Rochester, Minn.

"Hormonal Influences," Albert S. Gordon, Graduate School of Arts and Science, New York University, New York, N.Y.

DEFENSE FUNCTIONS OF THE LEUKOCYTES

Afternoon Sessions. Chairman: Charles A. Doan

"Chemotaxis and Locomotion of Leukocytes," Morton McCutcheon, School of Medicine, University of Pennsylvania, Philadelphia, Penna.

"Leukocytic Phagocytosis," Claude-Starr Wright, Ohio State University, College of Medicine, Columbus, Ohio.

"Leukocytes Involved in Antibody Formation," Albert H. Coons, Harvard Medical School, Boston, Mass.

"Leukocytes and the Inflammatory Response," Valy Menkin, Temple University, School of Medicine, Philadelphia, Penna.

Saturday, May 29

CHEMICAL AND METABOLIC ASPECTS OF LEUKOCYTIC ACTIVITY

Morning Session. Chairman: Nathan Rosenthal

"Metabolism of Leukocytes," S. P. Martin, Duke University, Durham, N.C.

"Leukocytic Enzymes," William N. Valentine, School of Medicine, University of California at Los Angeles, Los Angeles, Calif.

"Peptidases in Human Leukocytes," Gerald A. Fleisher, Mayo Clinic, Rochester, Minn.

"Leukocytic Oxidases," Paulo Seabra, Academia Nacional de Medicina, Rio de Janeiro, Brazil.

"Histochemistry of Leukocytes," Max Wachstein, St. Catherine's Hospital, Brooklyn, N.Y.

SECTION OF BIOLOGY
DIVISION OF MYCOLOGY

"SPECIATION AND VARIATION IN ASEXUAL FUNGI"

JUNE 4, 1954

The Section of Biology and the Division of Mycology held a conference on "Speciation and Variation in Asexual Fungi." Doctor Kenneth B. Raper, University of Wisconsin, Madison, Wisconsin, was the Conference Chairman in charge of the meeting.

The program consisted of the following papers:

Friday, June 4

Morning Session.

Introductory Remarks, Kenneth B. Raper, University of Wisconsin, Madison, Wis.

"Some Interrelationships of Speciation, Types, and Nomenclature in the Bacteria," R. E. Buchanan, Iowa State College, Ames, Iowa.

"Variation and Speciation in the Genus *Fusarium*," William C. Snyder, University of California, Berkeley, Calif.

"The Evolution of Species Concepts in *Aspergillus* and *Penicillium*," Charles Thom, Port Jefferson, N.Y., and Kenneth B. Raper, University of Wisconsin, Madison, Wis.

"Spontaneous and Induced Variation in Selected Stocks of the *Penicellium chrysogenum* Series," J. F. Stauffer and M. P. Backus, University of Wisconsin, Madison, Wis.

"Environmental Control of Morphogenesis in Microorganisms," Walter J. Nickerson, Rutgers University, New Brunswick, N.J.

"Natural and Cultural Variation in Entomogenous Fungi Imperfecti," Donald MacLeod, Laboratory of Insect Pathology, Sault Ste. Marie, Ontario, Canada, and Institute of Microbiology, Rutgers University, New Brunswick, N.J.

Afternoon Session.

"Types of Variation in *Actinomycetes*," B. M. Duggar, E. J. Backus, and T. H. Campbell, Lederle Laboratories, Pearl River, N.Y.

"Variations in *Streptomyces aureofaciens*," E. J. Backus, B. M. Duggar, and T. H. Campbell, Lederle Laboratories, Pearl River, N.Y.

"Criteria for the Species of *Streptomyces*," Paul R. Burkholder, University of Georgia, Athens, Ga.

"Variation in *Streptomyces*," K. L. Jones, University of Michigan, Ann Arbor, Mich.

"Useful Criteria for Species Differentiation in the Genus *Streptomyces*," C. W. Hesseltine, R. G. Benedict, and T. G. Pridham, Northern Utilization Research Branch, U.S. Department of Agriculture, Peoria, Ill.

Evening Session.

"Ektachrome Transparencies as Aids in Actinomycete Classification," Alma Dietz, Research Division, The Upjohn Company, Kalamazoo, Mich.

"Induced Mutation and Strain Selection in Industrially Important Microorganisms," Eugene L. Dulaney, Research Laboratories, Merck & Co., Rahway, N.J.

"Criteria for Speciation in the Genus *Nocardia*," N. M. McClung, University of Kansas, Lawrence, Kans.

NEW MEMBERS

Elected May 17, 1954

LIFE MEMBERSHIP

Webster, Jerome P., M.D., Biology. Professor, Clinical Surgery, College of Physicians and Surgeons, Columbia University, New York, N.Y.

SUSTAINING MEMBERSHIP

Butcher, Leonard Vinter, D.V.M., Public Health. Instructor, Large Animal Medicine, Tuskegee Institute, Ala.

Goldstein, Martin J., D.O., Biology, Medicine. Private Practice, Roscoe, N.Y.

Lum, Ralph J., Jr., M.D., Pharmacology. Assistant Professor, University of Puerto Rico, Santurce, P.R.

Wolfe, Ruth L., M.D., Biology. Medical Director, Hoffman-La Roche Limited, Montreal, P.Q. Canada.

ACTIVE MEMBERSHIP

Adamis, Dionysios, M.D., Medicine. Research Fellow in Medicine, Boston City Hospital, Boston, Mass.

Alessandrini, Sandro, M.D., Gastroenterology. Research Fellow in Nutrition, Hospital University of Pennsylvania, Philadelphia, Pa.

Amos, Harold, Ph.D., Bacteriology. Instructor, Department of Bacteriology, Harvard Medical School, Boston, Mass.

Anday, George J., M.D., Hematology, Cytology. Associate Clinical Professor, Medicine, Stritch School of Medicine, Loyola University, Chicago, Ill.

Anderson, Subbeal S., D.D.S., Dentistry. Private Practice, New York, N.Y.

Antonitis, Joseph J., Ph.D., Experimental Psychology. Associate Professor, Psychology, University of Maine, Orono, Maine.

Arther, Richard O., B.S., Psychology. Director, John E. Reid and Associates, New York, N.Y.

Banowitch, Morris M., M.D., Infectious and Metabolic Diseases. Clinical Professor of Medicine, College of Medicine, State University of New York, Brooklyn, N.Y.

Baranco, Raymond M., Sr., M.D., Medicine, Biology. Director, Health Services, Southern University, Baton Rouge, La.

Bartlett, J. H., Ph.D., Physics. Professor of Physics, University of Illinois, Urbana, Ill.

Bastian, James Winslow, Ph.D., Physiology. Pharmacologist, Armour Laboratories, Chicago, Ill.

Bauer, Jere M., M.D., Cancer Research. Assistant Professor, Internal Medicine, University of Michigan, Ann Arbor, Mich.

Baumgartner, Renée, M.D., Pharmacology. Chief, Medical Department, Gergy Pharmaceutical Company, New York, N.Y.

Baxter, Earl Hayes, M.D., Pediatrics. Chairman, Department of Pediatrics, Ohio State University, Columbus, Ohio.

Beattie, James R., Pharmaceuticals. Director, Public Relations, Ciba Pharmaceutical Products Inc., Summit, N.J.

Behrens, Charles Frederick, M.D., Radiology. District Medical Officer, Headquarters Sixth Naval District, Naval Base, Charleston, S.C.

Bell, Maurice E., Ph.D., Physics, Operations Research. Manager, Plans Division, Missile Systems Laboratory, Sylvania Electric Product Inc., Bayside, N.Y.

Bennett, George A., M.D., Anatomy. Dean, Jefferson Medical College, Philadelphia, Pa.

Beranek, Leo Leroy, D.Sc., Acoustics. Associate Professor, Communication Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Berger, Carl, Ph.D., Physical Chemistry. Project Supervisor, Commonwealth Engineering Company, Dayton, Ohio.

Bergman, Bernard, Ph.D., Sociology. Rabbi, New York, N.Y.

Berlin, David D., M.D., Surgery. Clinical Professor, Tufts College, Medford, Mass.

Billen, Daniel, Ph.D., Bacterial Physiology. Biologist, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Blackwell, J. H., Ph.D., Physics. Assistant Professor, University of Western Ontario, London, Ont. Canada.

Blake, Howard W., D.D.S., Dental Research. Private Practice, New York, N.Y.

Block, Mathew, M.D., Hematology. Associate Professor of Medicine, University of Colorado, Denver, Colo.

Bohr, David F., M.D., Cardio-vascular Physiology. Associate Professor of Physiology, University of Michigan, Ann Arbor, Mich.

Bomse, Emanuel M., M.D., Biology, Anthropology. Assistant in Pediatrics, Maimonides Hospital, Brooklyn, N.Y.

Bond, V. P., M.D., Radiobiology. Head, Experimental Pathology Branch, Biological and Medical Sciences Division, U.S. Naval Radiological Defense Laboratory, San Francisco, Calif.

Boord, Cecil E., Ph.D., Organic Chemistry. Research Professor in Chemistry, Ohio State University, Columbus, Ohio.

Boyd, David A., Jr., M.D., Neurology, Psychiatry. Consultant, Mayo Clinic, Rochester, Minn.

Branch, C. H. Hardin, M.D., Psychiatry. Professor and Head, Department of Psychiatry, University of Utah, Salt Lake City, Utah.

Brenard, Fernand Charles G., Mathematics. Director, Belgian Center for Economic Research, Brussels, Belgium.

Brennan, Michael James, M.D., Internal Medicine, Hematology. Chief, Medical Service U.S. Army Hospital, Fort Monmouth, N.J.

Bronfin, Gerald J., M.D., Internal Medicine. Private Practice, Denver, Colo.

Brown, Dugald E. S., Ph.D., Physiology. Professor and Chairman, Department of Zoology. University of Michigan, Ann Arbor, Mich.

Brown, Kenneth D., Ph.D., Biochemistry. Assistant Professor, Biochemistry, Marquette University, Milwaukee, Wis.

Brown, Russell Wilfrid, Ph.D., Bacteriology. Director, Carver Foundation, Tuskegee Institute, Ala.

Brown, Walter N., Jr., Ph.D., Physics, Electronic Engineering. Director, Bone Density Research and Evaluation Center, Pennsylvania State College, State College, Pa.

Brucer, Marshall, M.D., Medicine, Medical Physics. Chairman, The Medical Division, Oak Ridge Institute of Nuclear Studies Inc., Oak Ridge, Tenn.

Bruenn, Howard G., M.D., Medicine, Cardiology. Assistant Professor, Clinical Medicine, College of Physicians and Surgeons, Columbia University, New York, N.Y.

Bubert, Howard Matheson, M.D., Medicine. Associate Professor, Medicine, Chief Allergy Section, Chairman and Director Postgraduate Committee, University of Maryland, Baltimore, Md.

Buchanan, John Machlin, Ph.D., Biochemistry. Professor and Head, Division of Biochemistry, Massachusetts Institute of Technology, Cambridge, Mass.

Buchin, Irving, D.D.S., Orthodontics. Private Practice, Forest Hills, N.Y.

Buras, Isaac, D.D.S., Oral Surgery. Chief Dental Officer, Israel Navy, Israel.

Calbick, Chester J., B.Sc., Electron Microscopy. Technical Staff, Bell Telephone Laboratories, Murray Hill, N.J.

Carlson, Hilding B., Ph.D., Psychology. Associate Dean of Students, San Diego State College, San Diego, Calif.

Carter, Wilbert Kennith, M.A., Anthropology. Lecturer, Tufts College, Medford, Mass.

Cashin, William M., Ph.D., Atomic Power. Supervisor, Duels Research Unit, Metallurgy Section, Knolls Atomic Power Laboratory, General Electric Company, Schenectady, N.Y.

Castleman, Leonard, M.D., Internal Medicine. Private Practice, Brooklyn, N.Y.

Catlin, B. Wesley, Ph.D., Microbiology. Assistant Professor, Microbiology, Marquette University, Milwaukee, Wis.

Chambers, F. W., Jr., Medicine, Surgery. Bureau of Medicine and Surgery, Department of the Navy, Washington, D.C.

Chapman, George Bunker, Ph.D., Cytology. Research Biologist, R.C.A. Laboratories, Princeton, N.J.

Chilcote, Max E., Ph.D., Biochemistry. Associate Professor, University of Buffalo, Buffalo, N.Y.

Clark, Byron B., Ph.D., Pharmacology. Professor and Chairman, Tufts College, Boston, Mass.

Coblentz, Adrien L., M.D., Psychiatry. Psychiatrist, Medical Corp., San Francisco, Calif.

Conn, Hadley L., Jr., M.D., Cardiovascular Physiology. Associate Scientist, Division of Physiology, Brookhaven National Laboratory, Upton, N.Y.

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Cooper, Herbert Kurtz, D.Sc., D.D.S., Cleft Palate. Director, Lancaster Cleft Palate Clinic, Lancaster, Pa.

Cowie, Dean B., B.S., Microbiology, Nuclear Physics. Staff Member, Carnegie Institution of Washington, Washington, D.C.

Cronkite, Eugene P., M.D., Hematology. Head, Naval Medical Research Institute, Bethesda, Md.

Curran, Charles A., Ph.D., Psychology. Lecturer, University of Louvain, Belgium.

Dahl, Anthony Orville, Ph.D., Botany, Cytology, Palynology. Professor, Chairman, Department of Botany, University of Minnesota, Minneapolis, Minn.

Dauer, Maxwell, Ph.D., Radiologic Physics. Research Physicist, Army Medical Service Graduate School, Washington, D.C.

Davenport, Fred M., D.Sc., Epidemiology, Internal Medicine. Associate Professor, Epidemiology, Virology Laboratory, University Laboratory, University of Michigan, Ann Arbor, Mich.

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Deubler, Mary Josephine, Ph.D., D.V.M., Veterinary Clinical Pathology, Mycology. Assistant Instructor, Veterinary Pathology, University of Pennsylvania, Philadelphia, Pa.

Dicke, R. H., Ph.D., Nuclear Physics. Associate Professor, Physics, Palmer Physical Laboratory, Princeton University, Princeton, N.J.

Dobbs, Edward C., D.D.S., Pharmacology. Professor, Pharmacology, Dental School, University of Maryland, Baltimore, Md.

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Dolman, C. E., Ph.D., Bacteriology, Immunology. Professor, Head, Department of Bacteriology, University of British Columbia, Vancouver, B.C., Canada.

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Ducoff, Howard S., Ph.D., Cell Physiology. Associate Biologist, Argonne National Laboratory, Lemont, Ill.

Dunbar, Maxwell John, Ph.D., Marine Biology. Associate Professor, Zoology, McGill University, Montreal, P.Q., Canada.

Dunham, Charles Little, M.D., Internal Medicine. Chief, Medical Branch, Division of Biology and Medicine, U.S. Atomic Energy Commission, Washington, D.C.

Elliott, Irvin W., Ph.D., Organic Chemistry. Professor, Chemistry, Florida A. & M. University Tallahassee, Fla.

Ellis, Lillian N., Ph.D., Chemistry. Professor, Chemistry, Adelphi College, Garden City, N.Y.

Eschenbrenner, Allen B., M.D., Cancer. Pathologist, Virus and Rickettsial Section, U.S. Public Health Service, Montgomery, Ala.

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Flexner, Louis B., M.D., Anatomy. Chairman, Department of Anatomy, University of Pennsylvania, Philadelphia, Pa.

Freedman, M. Joel, D.D.S., Dentistry. Instructor, New York University Dental College, New York, N.Y.

Fuchs, Andre Lucian, D.D.S., Silencology, Bruitology. Private Research, Private Practice, New York, N.Y.

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Gansloser, Wilbert M., M.D., Psychiatry. Assistant Professor, St. Louis University, St. Louis, Mo.

Garrison, Warren M., Ph.D., Radiation Chemistry. Chemist, Radiation Laboratory, University of California, Berkeley, Calif.

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Goldstein, Hyman, M.D., D.Sc., Mongolism and Non-Mongoloid Mental Retardation in Children, Consultant Pediatrician and Endocrinologist, Manhattan General Hospital, New York, N.Y.

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Herrera, Nilo Ernesto, M.D., Pathology, Neoplasms. Instructor, Pathology, University of Vermont, Junior Associate Pathologist, Mary Fletcher Hospital, Burlington, Vt.

Herzog, Elaine P. Zinker, M.A., Biochemistry. Chief Biochemist, Hektoen Institute for Medical Research, Chicago, Ill.

Hess, William R., Ph.D., Immunology, Virology. Immunologist, Department of Agriculture, Plum Island Animal Disease Laboratory, Orient, N.Y.

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Hoch, Paul H., M.D., Neurology, Psychiatry. Principal Research Psychiatrist, New York State Psychiatric Institute, New York, N.Y.

Hoelscher, H. E., Ph.D., Chemical Engineering. Assistant Professor, Chemical Engineering, The Johns Hopkins University, Baltimore, Md.

Howard, William H. R., M.D., Diagnostic Radiology. Radiologist, The Children's Hospital, Columbus, Ohio.

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Hurley, Harry J., Jr., M.D., Physiology. Dermatologist, Army Medical Research Laboratory, Fort Knox, Ky.

Ingram, Marylou, M.D., Radiation Biology, Hematology. Chief, Hematology Section, University of Rochester Atomic Energy Project, Rochester, N.Y.

Irwin, Samuel, Ph.D., Neuropharmacology. Pharmacologist, Schering Corporation, Bloomfield, N.J.

Jacobson, Lillian E., M.A., Radiation Physics. Radiation Physicist, Montefiore Hospital, New York, N.Y.

Jay, James, D.D.S., Orthodontics, Dentistry. Assistant Professor, Orthodontics, Columbia University, New York, N.Y.

Kahn, Julius B., Ph.D., Pharmacology. Assistant Professor, Pharmacology, University of Cincinnati, Cincinnati, Ohio.

Kauffmann, Joseph H., D.D.S., Biology, Biochemistry. Private Practice, New York, N.Y.

Kennedy, Charles, M.D., Neurophysiology. Research Fellow, Pediatric Neurology, Children's Hospital, Philadelphia, Pa.

Kennedy, David P., Physics, Mathematics. Research, Raytheon Manufacturing Company, Waltham, Mass.

Kerman, Herbert David, M.D., Radiology. Associate Professor, Radiology, University of Louisville, Louisville, Ky.

Kindred, Robert G., M.D., Medicine, Musculoskeletal Diseases and Trauma. Medical Officer in Charge, Tissue Bank, Naval Medical School, Bethesda, Md.

Kingston, Robert H., Ph.D., Solid State Physics. Staff Member, Lincoln Laboratory, Lexington, Mass.

Kittay, Irving, D.D.S., Muscle Physiology, Periodontology. Private Practice, New York, N.Y.

Koletsky, Simon, M.D., Experimental Pathology. Professor, Western Reserve University, Cleveland, Ohio.

Kornberg, Harry A., Ph.D., Radiobiology. Manager, Biology Section, General Electric Company, Richland, Wash.

Krakaur, Richard B., M.D., Biochemistry, Clinical Pathology. Chief, Chemistry Section, First Army Medical Laboratory, New York, N.Y.

Krulee, Gilbert K., Ph.D., Psychology. Research Assistant, Professor of Psychology, Tufts College, Medford, Mass.

Laurence, M. K., M.D., Internal Medicine. Private Practice, Swampscott, Mass.

Leung, S. Wah, D.D.S., Ph.D., Dentistry, Physiology. Professor and Head, Department of Physiology, University of Pittsburgh School of Dentistry, Pittsburgh, Pa.

Lowenstein, Louis, M.D., Hematology. Associate Physician, Hematologist in Charge, Royal Victoria Hospital, Montreal, P.Q., Canada.

Lyons, Harry, D.D.S., Dentistry, Peridontology. Dean, School of Dentistry, Medical College of Virginia, Richmond, Va.

Mack, Walter N., Ph.D., Bacteriology, Viruses. Associate Professor, Michigan State College, East Lansing, Mich.

Marjerison, Howard M., D.Sc., D.M.D., Dentistry for Children. Director, Forsyth Dental Infirmary for Children, Boston, Mass.

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